McKinsey and Company, Inc.

AN EVALUATION OF NASA'S CONTRACTING POLICIES, ORGANIZATION, AND PERFORMANCE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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McKinsey & Company, Inc.

Management Consultants

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Cafritz Building
1625 I Street, NW.
Washington 6, D.C.

October 28, 1960

Dr. T. Keith Glennan
Administrator
National Aeronautics and
Space Administration
Washington 25, D.C.

Dear Dr. Glennan:

We have completed the study of NASA's contracting policies and industrial relationships called for by Contract No. NASw-144. The accompanying report sets forth our recommendations. These have been reviewed with you and with members of your staff. Hence, implementing actions on a number of the recommendations are already under way.

Questions to be Answered

This contract* directed us to study seven questions related to NASA's contracting policies, processes, and industrial relationships:

1. What role should the space flight centers play in contracting? And how does this role relate to the need for in-house development and engineering capabilities?

2. Under what circumstances, and for what reasons should NASA employ each of the following in systems management: A development center? An industrial contractor as systems manager? An industrial contractor as systems manager and prime contractor? A university or non-profit contractor as systems manager?

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* - Abstracted from the memorandum entitled "A Plan for Appraising NASA's Contracting Policies and Industry Relationships", addressed to Dr. T. Keith Glennan, February 20, 1960.

3. How and to what extent should NASA encourage elements of U. S. industry not now interested in or involved in space technology to enter the field?

4. What approaches and techniques should NASA use in supervising contractor operations and in evaluating contractor performance from both a technical and an administrative point of view?

5. What new incentives can be provided to induce industrial contractors to control costs and increase performance?

6. To what extent is NASA limited by the governmental framework in making desirable changes in its approaches to contracting and in tis relationships with contractors?

7. What problems does NASA's present approach cause in terms of the Agency's internal structure and processes?

Our study revealed additional problems that warranted inquiry. For example, it emphasized the considerable importance of the manner in which NASA plans complex development projects and organizes its staff to carry out these projects, including the letting of contracts involved and the supervision of contractors. Such problems have simultaneously been studied.

Outline of
Report

The accompanying report presents answers to these and related questions and our recommendations for action. In summary terms:

Chapter 1 depicts the magnitude, nature and importance of NASA's contracting job and summarizes our recommendations.

Chapter 2 deals with the critical question as to what NASA's space flight centers should do "in-house" and what NASA should contract for. This chapter affords answers to questions 1, 2, and 3 above.

Chapter 3 spells out our recommendations as to how the responsibilities for systems integration and project management can be better organized and performed within NASA. This chapter deals especially with question 2 and related matters.

Chapter 4 deals with the central and critical problem of NASA's continuing relationships with the enterprises to which contracts are let. It presents answers to questions 4, 5, and 6.

Chapter 5 presents recommendations for the improvement of the organization of the procurement function throughout NASA.

* * *

We appreciate the additional opportunity to serve you and NASA that this study has afforded us. We are indebted to you and to many of your associates for their cooperative assistance during the course of this study. We will welcome your suggestions as to how we may assist you in obtaining the full benefits to be derived from this study.

Respectfully submitted,

McKinsey & Company, Inc.

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AN EVALUATION OF NASA'S CONTRACTING POLICIES, ORGANIZATION, AND PERFORMANCE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

1 - HOW BETTER TO PERFORM NASA'S CONTRACTING JOB - A SUMMARY OF RECOMMENDATIONS

IMPORTANCE OF CONTRACTING TO NASA'S TOTAL JOB

No single element of NASA's management is as essential to the accomplishment of NASA's job as the ability to contract effectively for the research, development, production, and services required. The volume of work to be done and the vast range of scientific and engineering skills involved require that NASA utilize effectively through contracts those enterprises - universities or business firms - that possess the skills required.

Approximately 85 percent of NASA's annual appropriations, hence, are spent on contracts. This fact is illustrated by the following table:

	Estimated Obligations FY 1960 (millions)		Budget Estimate FY 1961 (millions)	
	Dollars	Percent	Dollars	Percent
Contracts	468	85.2	770	84.2
Personnel	81	14.8	145*	15.8
Total	549	100.0	915	100.0

* - Increase due largely to added personnel costs resulting from transfer of Development Operations Division (Marshall Space Flight Center) from Army to NASA effective beginning with Fiscal Year 1961.

FACTORS THAT CONDITION NASA'S CONTRACTING JOB

The manner in which the contracting job is carried out is conditioned by four factors - (1) the unique characteristics of NASA's job, (2) the legislative framework within which NASA operates, (3) the political sensitivity of contracting, and (4) the manner in which NASA came into being.

(a) Characteristics of NASA's Job

NASA's ultimate objective is the acquisition, evaluation, and dissemination of scientific information. Space vehicles and associated hardware provide the tools to achieve this objective. This means that most of NASA's contract dollars go for never-before-produced experimental equipment and systems, requiring diverse engineering and scientific skills.

The bulk of NASA's contracting, hence, is carried out on a cost-plus-fixed-fee basis. This method of contracting demands a closer day-to-day working relationship between NASA's technical and procurement specialists than other methods of procurement in such areas as the preparation of work statements, analyses of costs, in selecting suppliers, and in progress reporting and evaluation.

Contracting for such efforts is complicated further by the fact that many projects utilize industrial resources on what is essentially a "one time basis". The enterprise that contracts to carry out a NASA project may have to assemble scientists, engineers, technicians, and facilities especially adapted to an unprecedented undertaking. Upon completion of the project the "team" and facilities may no longer be required. There is little need for the repetitive production of a succession of items (e.g., as in aircraft or even military missile systems) but for the production of a single or very limited number of launch vehicles and space craft. Procurement of a small number of unique items places major stress on the reliability of each item.

The high reliability requirements, plus the small number of similar units that are used, are central characteristics that distinguish and complicate NASA's procurement job. These characteristics mean that the normal cost and performance incentives are often not available to NASA and contractors. Therefore, NASA must substitute for the self-discipline of such incentives continual and effective technical supervision of contractor's efforts.

Over and above its own immediate needs for the services of industrial enterprises, NASA has a longer-run obligation in a free enterprise society to provide industry opportunities to take advantage of the commercial aspects of space research and development.*

The goods and services that NASA contracts for and the distribution of contracts among suppliers inevitably condition the capacity of American industry and of individual enterprises to participate in those areas where (a) commercial applications are foreseeable, e.g., communications, and (b) where space research and development has an indirect impact on industrial technology and commercial products, e.g., electronics.

These factors also determine the extent of economic concentration or dispersion that will characterize the supplying industry in the decades ahead. At present, relatively few industrial concerns possess the engineering and scientific skills requisite to the successful completion of a total space vehicle subsystem such as the launch or space vehicle. However, unless industrial contractors are encouraged to round out their capabilities, NASA will find it necessary to expand its in-house capabilities - facilities and personnel wise.

(b) The Legal Framework of Contracting

The National Aeronautics and Space Act of 1958 provided NASA broad authority "to enter into . . . and perform such contracts . . . or other transactions as may be necessary to the conduct of its work and on such terms as it may deem appropriate". The Act also made applicable to NASA the provisions of the Armed Services Procurement Act of 1947.

These legislative grants of procurement authority were designed (1) to grant NASA the same flexibility in procurement as is available to the military and (2) to avoid the imposition of an additional set of procurement regulations with which industry would have to cope. This latter point is of particular

* - Some of the problems involved were set forth in an address by Ralph J. Cordiner, Chairman of the Board, General Electric Company, entitled "Competitive Private Enterprise in Space" at the University of California, Los Angeles, May 14, 1960.

significance since a substantial proportion of NASA's requirements are similar to those of the military departments and are produced by the same companies.

The contracting authority granted by the Congress has made it possible for NASA to depend on the military departments during its first two years of existence for substantial assistance in contracting. Without this assistance it would have been impossible for NASA to have achieved as much in the time that has elapsed. However, this dependence has influenced the speed and effectiveness with which NASA has developed its own organization and contracting processes. It has also limited the extent to which NASA has been able to initiate new approaches and techniques for contracting for research and development.

(c) Political Sensitivity of Contracting

No aspect of NASA's job is more politically sensitive than the contracting process. In substantial part this political sensitivity arises out of the large value of the contracts being let and their significance to individual contractors and to the communities in which their plants are located. A second cause of this sensitivity is the fact that the contracting activities of large government agencies have become instruments for achieving indirect objectives. These include (1) assisting small business, (2) channeling public funds into depressed and labor surplus areas, (3) maintaining a broad national industrial base for mobilization, and (4) supporting academic and institutional programs.

NASA's public and Congressional relations will depend, in considerable part, upon the manner in which the contracting process is carried out.

(d) NASA's Organizational Inheritance

NASA's organization was built on the foundations of the NACA laboratories. The traditional job of these laboratories had been in-house supporting research for the military departments and the aircraft industry. Their staffs had little experience in contracting for complex development projects.

The Jet Propulsion Laboratory, prior to its transfer to NASA, had been primarily concerned with the in-house development of Army missile systems. Although this laboratory had spent approximately half of its annual budget via contractors and vendors, the items contracted for consisted primarily of raw materials, parts, components, and similar items. Laboratory personnel possessed little or no experience in contracting with industry for major subsystems of the nature involved in NASA's program.

The individuals making up these groups had been primarily concerned with in-house development and had had little experience in utilizing non-governmental contractors for development of subsystems as distinguished from components. The staff of the Development Operations Division of the Army Ballistic Missile Agency had had a markedly different experience but this staff was similarly oriented toward in-house development.

A further factor conditioning NASA's contracting processes was the inheritance by this Agency of a number of projects that had already been initiated by other agencies. These include the Vapor Magnetometer Project, initiated by the Naval Research Laboratory; the Saturn launch vehicle by the Advanced Research Projects Agency of the Department of Defense and the Development Operations Division of the Army Ballistic Missile Agency; the Centaur launch vehicle initiated by the Air Force; Tiros I, a project conceived and initiated by the Army Signal Corps; and Echo, a project developed by the Langley Research Center of NACA.

Each of these projects involved differing approaches to (a) the division of effort between government and private resources, (b) project management, (c) technical supervision of contractor efforts, (d) contract administration, and (e) progress reporting, including financial and procurement control processes.

METHOD OF ANALYSIS

In studying NASA's approach to its contracting job, we took the pragmatic approach of analyzing step-by-step twelve significant space flight and launch vehicle projects. The projects studied are identified in Table 1 - "Framework for Analyzing NASA's Contracting Policies". * For each project, we studied the:

* - In addition to the projects listed, we examined various aspects of contracts for the F-1 engine; Minitrack; Research Grants and Contracts at Johns Hopkins and Stanford Universities and at the Massachusetts Institute of Technology; Atlas-Able Space Probe; Snap 8; GE Plug Nozzle engine; nuclear rocket pump; and Deep Space Net.

1. Division of effort between NASA and private contractors in terms of the major elements (e.g., detailed design) that comprise each project.

2. Varying approaches employed in contracting, i.e., relying for the whole project on a single contractor, procuring subsystems from various contractors, and procuring components to be assembled within NASA.

3. Varying approaches employed in project management.

4. Techniques employed in technical supervision and administration of contracts.

In addition to these analyses of NASA's experience, we:

1. Studied the working relationships between technical and procurement staffs in the headquarters and in the field centers.

2. Acquainted ourselves with the comparable contracting experience of other agencies, i.e., the Departments of the Air Force, Navy, Army, and the Atomic Energy Commission.

SUMMARY OF RECOMMENDATIONS

The results of these analyses are set forth in the following chapters of this report. Here we summarize those recommendations on which action has already been initiated or on which we urge that action be taken.

1. NASA has made significant progress in reorienting staffs that had been oriented toward in-house research and development and in increasing the utilization of industrial enterprises and other non-governmental contractors. To stimulate further contracting out, we recommend that NASA approve and generally promulgate the following criteria to govern what work shall be done in-house, and what shall be contracted out:

(a) NASA should retain in-house the conceptual and preliminary design elements of a major project, or its equivalent, in each major program.*

* - Major programs include - (1) Applications, (2) Manned Space Flight, (3) Lunar and Planetary, (4) Scientific Satellite, (5) Sounding Rocket, and (6) Launch Vehicle. See Appendix A for definitions.

TABLE 1

FRAMEWORK FOR ANALYZING

NASA'S CONTRACTING POLICIES

Space Flight Projects	Estimated Obligations FY 1960* (Millions of Dollars) In-House	Out-of-House	Distribution of Responsibilities: Program Mgmt	Project Mgmt	Contract Admin.	Principal Contractors
Mercury	3.8	87.2	OSFP	STG	Navy/AF	McDonnell, Convair, Western Electric**
Ranger	5.5	10.9	OSFP	JPL	Air Force	Convair, Lockheed
OAO	0.5	0.3	OSFP	GSFC	Air Force	Convair, Lockheed
S-16	0.05	2.1	OSFP	GSFC	Air Force	Douglas, Ball Brothers
P-14	0.7	0.2	OSFP	GSFC	Air Force	Douglas, MIT, Varlan
Echo	0.05	3.2	OSFP	GSFC	Air Force	Douglas, Bell Telephone, General Mills, MMM
Launch Vehicle Projects						
Saturn	43.0	135.3	OLVP	MSFC	Air Force	Douglas, Convair, Rocketdyne
Centaur	0.2	36.5	OLVP	MSFC	Air Force	Convair, Rocketdyne
Agena-B	0.1	7.3	OLVP	JPL	Air Force	Convair, Lockheed
Delta	0.7	11.8	OLVP	OLVP	Air Force	Douglas
Scout	0.05	2.5	OLVP	Langley RC	Navy	Chance Vought
Vega	0.1	3.5	OLVP	OLVP/JPL	Air Force	Convair
Total $	56.1	300.8				
Total %	18.8	81.2				

* - The in-house estimates include obligations from the Salaries and Expenses Appropriation; out-of-house obligations from the Research and Development Appropriation. The estimates were obtained from the various project managers and reflect general magnitudes only.

** - The Western Electric contract for the Mercury tracking system is supervised by the Langley Research Center.

(b) NASA's in-house efforts in the conceptual and preliminary design elements of space flight and launch vehicle projects should be supplemented extensively through the use of study contracts.

(c) NASA should retain in-house the detailed design, fabrication, assembly, test and check out elements of a single advanced launch vehicle* and spacecraft unique to each major program.

(d) Each center should contract out the detailed design, fabrication, assembly, test, and check out elements of all launch vehicles and spacecraft except the relatively few required to meet the criteria set forth in item (c) above.

(e) NASA's centers should contract all production manufacturing efforts including the standard or relatively standard parts and components used for in-house launch vehicles and spacecraft of an advanced developmental nature.

(f) NASA should contract out total space vehicles including the physical integration of subsystems, i.e., the launch vehicle and spacecraft.

(g) NASA should contract with the external scientific community for a preponderant proportion (70 to 85 percent) of all space flight experiments.

Adoption of these criteria will ensure the retention in-house of the capability required to enable NASA effectively to contract for the bulk of the research and development services needed. Adoption of the criteria will curb the tendency to do all that can be done in-house and contract out what remains.

2. To utilize its in-house facilities to the fullest, we recommend that NASA:

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* - Or stage in the case of a project such as the Saturn Launch Vehicle, i.e., the S-I Stage.

(a) Place responsibility for a limited number of development projects in the research centers where they have the capabilities required, and these capabilities are needed by NASA for the particular project.

(b) Establish project management teams in the Research Centers where this means a center's capabilities can best be utilized to provide needed development assistance.

3. The complex character of space vehicle subsystems makes inevitable the distribution of responsibility among several NASA centers and among industrial contractors. To resolve more effectively the technical (in matching up one space vehicle subsystem with another) and jurisdictional problems (headquarters staffs vs. center staffs) that arise, we recommend that NASA:

(a) Assign as full responsibility as practicable for the execution of each project to a specific center.

(b) Clarify the relative responsibilities of the headquarters staffs and the space flight centers by concentrating the efforts of the headquarters staffs on reviewing and approving:

(1) Development plans for each space flight project, including conceptual and preliminary designs and allocation of responsibilities in- and out-of-house.

(2) Schedules in terms of major procurement actions and technical milestones.

(3) Budget justifications and financial operating plans.

In addition, the headquarters technical staffs would evaluate projects and approve changes in the project plans which significantly alter objectives, schedules, and/or costs.

4. Strengthen the capabilities of the space flight centers to manage projects, particularly those in which major subsystems or total space flight vehicles are developed by contractors. To this end, we recommend that NASA:

(a) Improve the competence of its project managers. Steps must be taken to ensure that project managers develop the full complement of technical and managerial skills essential for this task. The "custom-tailored" training program for project management personnel that has been initiated is a promising step toward this end.

(b) Improve the project organizational arrangements that now exist. Each project management team responsible for a major space flight project should be headed by a full-time project manager reporting directly to the Director or Deputy Director of the responsible center.* Each project management team should include sufficient technical and administrative (e.g., financial, procurement) personnel to make the project manager effective in mobilizing the resources of the whole center, of other centers, and of the contractors.

5. NASA is faced with the major and complex task of developing, under cost-plus-fixed-fee contracts, working relationships with contractors which neither stifle the contractors' capabilities, nor relieve them of their obligations to use public funds wisely and economically. To this end, we recommend that NASA:

(a) Develop a guide for preparing and evaluating statements of work to be done and service to be rendered under research and development contracts.

(b) Institute a continuing program to assemble and study cost data as a basis for improving funding estimates.

(c) Provide a single point of ultimate technical authority for each contractor on a given project - the project manager.

(d) Establish guidelines as to the approaches and techniques to be used in technical supervision of contractors.

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* - Because of the inability to attract senior project managers at the salary level NASA is able to offer achievement of this objective will require, in a number of cases, a considerable period of time.

(e) Establish guidelines as to staff action on the analysis and control of costs in terms of pre-award analyses of prices, costs, and profits, and post-award cost control techniques.

(f) Continue to make its own source selections, handle its own contract negotiations, and provide its own technical supervision.

(g) Supplement use of the military services for "field service functions" by periodic evaluation of services rendered, direct handling when required in special situations, and approval of subcontracts within clearly prescribed criteria.

6. To overcome apparent deficiencies in the functioning of the headquarters Procurement and Supply Division, we recommend:

(a) Approval of the organizational plan prepared by the Director of the Procurement and Supply Division with one major exception; that is, focus all activities related to facilities planning and utilization in a separate division in the Office of Business Administration rather than in a branch of the Procurement and Supply Division.

(b) Development of a system of field center procurement reviews which will involve key personnel from each of the branches of the headquarters Procurement and Supply Division. This step plus the one recommended in item (a) above will make it possible to abolish what is presently termed the Field Installations Branch in the Procurement and Supply Division.

(c) Establishment of a position of Assistant Director in the Procurement and Supply Division.* The person appointed to fill this position should be given primary responsibility for the day-to-day internal management of the Division.

(d) Additional staff be made available, particularly in the Policies and Procedures Branch, for the Procurement Committee, and in the Procurement Assistance Branch.

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* - Action has been taken to establish such a position.

7. NASA's technical staffs have reflected lack of understanding of the processes that must be carried out if their needs for research and development services are to be translated into contracts with qualified suppliers and NASA's resources are to be conserved. To overcome this lack, we recommend that steps be taken to aid the technical staffs - in headquarters and in the centers - in expanding their understanding of the:

(a) Succession of actions that the procurement staff must take to negotiate and administer a contract.

(b) Importance of keeping procurement staffs advised of needs that will affect procurement actions.

(c) Importance of recognizing what constitutes contractual commitments and refraining from making them without advice from NASA procurement staffs.

(d) Importance of cost analysis and negotiation and tolerance of the time that is required.

There is no simple nor established method of creating understanding and acceptance of these points by technical personnel. The primary obligation falls on NASA's management. It is to establish in day-to-day practice - at headquarters and in the field centers - the concept of team action on procurement matters.

To implement this concept requires the availability of procurement personnel who are strongly program oriented, while at the same time possessing outstanding experience in, and a clear understanding of, the contracting processes associated with complex research and development projects - including their financial and program implications.

8. Most of the development contracts that are still being awarded and supervised by NASA headquarters can be associated either with a specific project or with the technical skills available in one of the field centers. Wherever this is the case these contracts should be technically supervised and administered from a given field center rather than from headquarters. In a very limited number of cases it may be appropriate for NASA headquarters to award and supervise contracts related to the development and feasibility of future programs. This should knowingly be the exception to the general rule.

8. All contracts now supervised from headquarters that can be associated either with a specific project or with the specific skills of one of the field centers should be technically supervised and administered from the field centers; for example, those advanced technology studies for the development of solid rocket motors which are technically supervised from headquarters and administered by the Goddard procurement office.

2 - THE DIVISION OF EFFORT BETWEEN NASA AND PRIVATE CONTRACTORS

The determination of how much and what work NASA should "contract out" and how much and what work it should do "in-house" is one of the most complex problems facing NASA's top management. In analyzing this problem, we shall consider in this chapter:

(a) The present division of effort between NASA and private contractors and the reasons for this division.

(b) Factors influencing the division of effort that should be maintained.

(c) Criteria that should guide the determination of what work shall be done in NASA's centers and what work shall be "contracted out".

THE PRESENT DIVISION OF EFFORT AND THE UNDERLYING REASONS

Table 1 depicts the extent to which each major category of work done in or for the three Space Flight Centers has been performed "in-house" or contracted out. Tables 2, 3, and 4 show the same distribution, in terms of estimated obligations, for the most significant program or project in each center over a three-year period.

The data presented in these tables reveal that:

1. None of the three Space Flight Centers will obligate more than approximately one-third of the available funds on in-house efforts in the fiscal year beginning July 1, 1960. JPL will obligate approximately 35 percent; Goddard, the smallest proportion - approximately 15 percent.

These variations in practice are attributable in some part to the differing orientations of the staffs that have been transferred to NASA to form the present Space Flight Centers. Goddard's staff was assembled in considerable part from the Navy "Vanguard Group", which relied substantially on outside contractors in developing the Vanguard satellite launching system. On the other hand, the staff of the Jet Propulsion Laboratory,

TABLE 1

DISTRIBUTION OF ESTIMATED OBLIGATIONS BY MAJOR CATEGORY OF EXPENDITURE FISCAL YEAR 1961

(Millions of Dollars)

Major Activity	Jet Propulsion Laboratory		Goddard Space Flight Center		Marshall Space Flight Center	
	Total In-House	Total Out-of-House	Total In-House	Total Out-of-House	Total In-House	Total Out-of-House
General Management	$16.2*	-	$ 7.0	-	$ 43.2	-
Supporting Research	5.1	$ 5.5	16.6	$ 14.5	2.4	$ 61.5
Development Programs	11	41.1	11.4	156.8	64.3	161.8
Sub Total	$32.3	$46.6	$35.0	$171.3	$109.9	$223.3
Construction	-	13.0	-	31.7	-	54.5
Total	$32.3	$59.6	$35.0	$203.0	$109.9	$277.8
Percent of Total	35.2%	64.8%	14.7%	85.3%	28.3%	71.7%

* - Includes all overhead burden including shop services and similar items. General Management category is not comparable among three Centers because of variations in accounting systems.

TABLE 2

JET PROPULSION LABORATORY - RANGER A PROGRAM *

ESTIMATED OBLIGATIONS FISCAL YEARS 1960, 1961, 1962

(Millions of Dollars)

Program Elements	FY 1960 In-House**	FY 1960 Out-of-House	FY 1961 In-House**	FY 1961 Out-of-House	FY 1962 In-House**	FY 1962 Out-of-House
Conceptual Design	$0.6	$ 0.2	$ 1.8	$ 0.5	$0.5	$ 0.1
Preliminary Design	2.3	0.8	4.5	1.9	0.7	1.0
Fabrication and Assembly	1.4	3.3	4.0	7.0	2.5	7.4
Checkout of Prototype and Operating Units	0.8	1.2	2.5	5.1	2.5	3.5
Launching	0.1	-	0.8	-	1.0	-
Data Acquisition	0.3	0.4	0.9	0.5	1.0	0.8
Systems Contract (Design through Checkout on the Capsule)		5.0		1.0		
TOTAL	$5.5	$10.9	$14.5	$16.0	$8.2	$12.8
Percent of Total	34%	66%	47.5%	52.5%	39%	41%

* - The Ranger A Program consists of five missions to be flown on Atlas - Agena B launch vehicles. They will have as their objective the development of spacecraft technology, and determination of lunar surface conditions and environment. Missions 3, 4, and 5 will impact the moon.

** - Represents total costs including overhead.

TABLE 3

SPACE TASK GROUP

MERCURY PROGRAM

ESTIMATED OBLIGATIONS[1] FISCAL YEARS 1959, 1960, 1961

(Millions of Dollars)

Program Elements	FY 1959 In-House[2]	FY 1959 Out-of-House[3]	FY 1960 In-House[2]	FY 1960 Out-of-House[3]	FY 1961 In-House[2]	FY 1961 Out-of-House[3]
A. Capsule						
Conceptual Design	$0.02	$ -	$0.02	$ -	$0.02	$ -
Prelim. Design	0.05	-	0.04	-	0.03	-
Detail Design	0.11	3.57	0.18	4.23	0.13	2.28
R & D Testing	0.26	3.00	0.37	5.11	0.27	4.15
Fabr. & Asmbly	0.04	18.73	0.10	40.87	0.15	32.46
Launching	0.18	-	0.35	-	0.62	-
Landing & Recovery	0.04	-	0.07	3.53	0.17	15.00
Data Analysis	0.05	-	0.06	-	0.27	-
Subtotal	$0.75	$25.30	$1.19	$53.74	$1.66	$53.89
B. Boosters						
Little Joe	0.03	2.85	0.03	-	0.01	-
Redstone	0.10	9.23	0.15	9.57	0.11	0.75
Atlas	0.12	8.76	0.19	13.89	0.30	24.90
Subtotal	$0.25	$20.84	$0.37	$23.46	$0.42	$25.65
C. Tracking and Communication	0.14	0.11	0.28	5.67	0.42	25.57
D. Astronauts & Train'g	0.18	0.13	0.34	3.71	0.29	2.29
E. Animal Program	0.02	0.04	0.04	0.59	0.06	0.35
F. Langley Personnel Support	0.83	-	0.93	-	0.56	-
G. STG Administration	0.24	-	0.65	-	0.84	-
Total	$2.41	$46.42	$3.80	$87.17	$4.25	$107.75
Percent of Total	5%	95%	4.4%	95.6%	4%	96%

[1]Excludes construction costs - e.g., tracking network (Western Electric Co.) for $33 million.

[2]Basically personnel costs.

[3]Includes funds transferred to other Government agencies and other NASA Centers as well as to industry.

TABLE 4

MARSHALL SPACE FLIGHT CENTER

SATURN VEHICLE PROJECT

ESTIMATED OBLIGATIONS[1] FISCAL YEARS 1959, 1960, 1961

(Millions of Dollars)

Program Elements	FY 1959		FY 1960		FY 1961	
	In-House[2]	Out-of-House[3]	In-House[2]	Out-of-House[3]	In-House[2]	Out-of-House[3]
Stages						
S-I						
Developm. Eng'g	$24.27	$ 7.84	$34.63	$16.10	$35.85	$ 22.10
Adv. Technology	-	-	-	6.00	-	-
Hardware, Materials & Tools	-	21.53	-	17.26	-	27.50
Reliability	0.39	0.43	4.41	6.50	4.46	15.00
Subtotal	$24.66	$29.80	$39.04	$45.86	$40.31	$ 64.60
S-IV						
Developm. Eng'g	0.94	1.00	1.34	15.35	1.36	27.00
Hardware	-	-	-	5.00	-	18.00
Subtotal	$ 0.94	$ 1.00	$ 1.34	$20.35	$ 1.36	$ 45.00
S-V						
Developm. Eng'g	$ -	$ -	$ 0.45	$ 2.00	$ 0.45	$ 10.00
Hardware	-	-	-	1.45	-	6.00
Subtotal	$ -	$ -	$ 0.45	$ 3.45	$ 0.45	$ 16.00
S-III						
Developm. Eng'g	$ -	$ -	$ 0.33	$ -	$ 0.34	$ 11.00
Hardware	-	-	-	-	-	4.00
Subtotal	$ -	$ -	$ 0.33	$ -	$ 0.34	$ 15.00
Propellants	$ -	$ -	$ -	$ 1.50	$ -	$ 7.00
SUBTOTAL STAGES	$25.60	$30.80	$41.16	$71.16	$42.46	$147.60

[1]Excludes construction costs.

[2]Basically personnel costs.

[3]Includes obligations to other NASA Centers and other agencies as well as to industry.

Marshall Space Flight Center

Saturn Vehicle Project

Estimated Obligations Fiscal Years 1959, 1960, 1961
(Continued)

(Millions of Dollars)

Program Elements	FY 1959 In-House	FY 1959 Out-of-House	FY 1960 In-House	FY 1960 Out-of-House	FY 1961 In-House	FY 1961 Out-of-House
Propulsion						
H-1 Engine						
Developm. Eng'g	$ 0.16	$ 6.88	$ 0.11	$10.00	$ 0.11	$ 8.40
Hardware	-	8.08	-	10.80	-	13.60
Subtotal	$ 0.16	$14.96	$ 0.11	$20.80	$ 0.11	$ 22.00
20K Engine						
Developm. Eng'g	$ 0.06	$ 1.00	$ 0.04	$16.10	$ 0.05	$ 18.00
Hardware	-	-	-	6.00	-	5.50
Subtotal	$ 0.06	$ 1.00	$ 0.04	$22.10	$ 0.05	$ 23.50
15K Engine						
Developm. Eng'g	$ -	$ 0.59	$ 0.04	$ 1.90	$ 0.05	$ 3.00
Hardware	-	-	-	1.50	-	2.40
Subtotal	$ -	$ 0.59	$ 0.04	$ 3.40	$ 0.05	$ 5.40
200K Engine	$ 0.08	$ -	$ 0.36	$ -	$ 0.36	$ 25.00
Propellants	$ -	$ 0.59	$ -	$ 6.47	$ -	$ 10.20
SUBTOTAL PROPULSION	$ 0.30	$17.14	$ 0.55	$52.77	$ 0.57	$ 86.10
Guidance						
Developm. Eng'g	$ 0.16	$ -	$ 0.56	$ 6.00	$ 0.56	$ 2.50
Hardware	-	0.15	-	1.00	-	2.00
SUBTOTAL GUIDANCE	$ 0.16	$ 0.15	$ 0.56	$ 7.00	$ 0.56	$ 4.50
Ground Support Equip.						
Developm. Eng'g	$ 1.01	$ 1.01	$ 0.45	$ 1.00	$ 0.45	$ 1.00
Hardware	-	2.02	-	3.40	-	3.00
SUBTOTAL GSE	$ 1.01	$ 3.03	$ 0.45	$ 4.40	$ 0.45	$ 4.00
Launch Operations	0.16	-	0.28	-	3.16	0.90
TOTAL SATURN	$27.23	$51.12	$43.00	$135.33	$47.20	$243.10
Percent of Total	34%	66%	24%	76%	16%	84%

while serving the Ordnance Corps of the Department of the Army, developed a complete weapons system - the Sergeant - in major part "in house".

They are attributable also to the fact that, in some degree, the Space Flight Centers are undergoing transition. The relatively small percentage of in-house effort at Goddard reflects, to a considerable degree, the fact that this center is still in its "early start up stage" - project and staff wise.

2. Each Space Flight Center has contracted out complete space flight subsystems to contractors following completion of conceptual and preliminary designs.* Many of the subsystems require substantial advanced technological contributions on the part of the contractors. They cover all of the major aspects of the technology - engines, structures, guidance, tracking and communications, and such related services as reliability analysis and data analysis. (See Tables 2, 3, and 4.)

FACTORS INFLUENCING DIVISION OF EFFORT

A realistic division of effort between NASA and private contractors must accommodate certain basic factors. In summary, these basic factors and their implications are as follows:

1. NASA has "inherited" substantial in-house technical capabilities which must be effectively utilized now and in the future. There is a necessity for a transition period while the major elements of NASA's "inherited" technical capabilities, particularly as represented by the Jet Propulsion Laboratory and the Marshall Space Flight Center, are shifted from an in-house weapons system development to the development of space flight systems through the extensive use of contractors.

The reorientation will have to be achieved gradually if the unique experience, capabilities, and facilities at the JPL, Marshall, and Goddard Space Flight Centers are to be retained and utilized effectively.

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* - In addition, industry has been called upon for limited amount of conceptual design effort - e.g., the study contracts for the Centaur soft landing spacecraft.

2. <u>The advent of economical commercial applications of space research and development appears to be distant</u>. The seeming remoteness of commercial opportunities in space lends a further distinctiveness to NASA's contracting problem. If NASA strives to enlist a substantial number of enterprises in space research and development, it may utilize industrial resources that might better be used elsewhere - both from a profit-making point of view and in terms of the general welfare of the Nation.

The nature of a free enterprise society dictates, however, that industry should be given as extensive a role as possible in those areas where (1) commercial applications can be envisaged (at the present time, the fields of communications, navigation, and meteorology) and (2) those areas where participation in space research and development will have an indirect impact on industrial technology and commercial products - e.g., the whole field of materials research, uses of liquid hydrogen, and electronics.*

3. <u>NASA's requirements are not particularly conducive to the economic utilization of American industrial resources</u>. NASA, in general, procures a small number of systems adequate for specific scientific experiments (e.g., Tiros involves two spacecraft and Nimbus, three spacecraft through calendar year 1963). However, to the extent NASA can standardize launch vehicles, spacecraft, guidance systems, and auxiliary power sources, the opportunities for economic utilization of contractors' efforts are markedly increased.

In addition, the small number of vehicle systems needed to achieve missions of national and international significance creates a demand for a degree of reliability seldom required of industrial contractors.

NASA's requirements also involve (a) much tighter time schedules than has historically been the case in complex development undertakings (e.g., Mercury as compared to the X-15 experimental aircraft) and (b) common use by industry and government of certain unique and costly

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* - Space oriented R & D "will have many applications outside the space program. At the same time we must remember that the space technologies are not being made out of whole cloth. They are for the most part extensions of industrial technologies for commercial and military purposes . . . . Thus, space research and industrial research mutually support each other". Ralph J. Cordiner, <u>Competitive Enterprise in Space</u>, May 4, 1960, page 4.

facilities and equipment (e.g., the Saturn static test stands). However, these two factors should not be over-emphasized in justifying the retention of work in the Space Flight Centers.

4. A relatively few industrial concerns presently possess the engineering and scientific skills requisite to the successful completion of a total space vehicle. The majority of NASA's present or potential contractors have experience in only certain space vehicle subsystems or components of launch vehicle and spacecraft subsystems. This does not mean that industrial firms cannot acquire such capability. Several contractors already have extensive experience as system integrating contractors - e.g., Convair, Lockheed, and Douglas.

Unless industrial contractors are encouraged to round out their capabilities, NASA will find it necessary to expand its in-house capabilities - facilities and personnel wise - to handle the complex vehicle systems of the future - i.e., those employing Launch vehicles such as Saturn, Nova, and beyond.

WHAT CRITERIA SHOULD NASA FOLLOW IN CONTRACTING?

Three general criteria - never officially promulgated - have guided the development of the in-house capabilities of NASA's Space Flight Centers:

1. Each center should possess a sufficient in-house technical capability to enable it to (a) conceive of space flight development and research projects, (b) develop technical specifications for private contractors, and (c) supervise contractor efforts to ensure high reliability of subsystems and components in their early development stages.

2. Each center should conduct sufficient in-house research and development to ensure continuing excellence of the scientific and technical staffs.

3. Each space flight center should rely primarily on the NASA research centers (Langley, Ames, and Lewis) as well as private resources (industries, universities, and non-profit institutions) for advanced research and on industry for development of all production-type work.*

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* - This criterion would permit the Space Flight Centers to retain a significant advanced and supporting research effort. This is done to facilitate the "feed back" between development and research that is felt necessary in a rapidly evolving technology.

These criteria should be made more definitive in terms of the specific elements of development projects that should be retained within the space flight centers and those elements that should be contracted out (e.g., detailed design). To this end, we recommend that the following criteria be used in determining the division of effort between NASA and private contractors:

1. NASA should retain in-house the conceptual and preliminary design elements of a major project, or its equivalent, in each major program.* NASA must maintain in-house sufficient capability to undertake the conceptual and preliminary design elements of development projects in each major program area - i.e., lunar, planetary, manned space flight scientific satellites, satellite applications, and launch vehicle systems - or to effectively review and approve conceptual and preliminary design elements of projects submitted by contractors.

Retention of these elements of a project are necessary to ensure that:

(a) Within NASA there is the technical ability to plan space flight programs (e.g., the interplanetary program) and select missions (e.g., instrumented Lunar soft landing). This task of making basic determinations of what exploration shall be undertaken and supported at the taxpayers' expense is a governmental function.

(b) Contractors are provided with sufficiently definitive requirements to submit proposals and produce end items that meet the reliability and schedule requirements of the NASA program.

(c) A sound basis exists for technical direction and supervision of contractor efforts on subsystems and components, and on the solution of technical problems involved in matching one subsystem with another.

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* - Major programs include (1) Applications, (2) Manned Space Flight, (3) Lunar and Planetary, (4) Scientific Satellite, (5) Sounding Rocket, and (6) Launch Vehicle. See Appendix A for definitions.

2. NASA's in-house efforts in the conceptual and preliminary design elements of space flight and launch vehicle projects should be supplemented extensively through the use of study contracts.* It is in these two elements, more than any others, that industry's participation in the civilian space program has been limited. However, in the last few months, NASA has taken several steps to provide industry additional opportunities to participate in the conceptual and preliminary design elements of space flight projects - e.g., study contracts for the soft landing Lunar spacecraft employing the Centaur launch vehicle have been awarded to four firms; a bidders' conference has been held preparatory to awarding study contracts for the development of conceptual design elements for the "Advanced Manned Program".

The selected use of study contracts will serve to round out industry's capabilities to handle additional elements of launch vehicle and space flight projects. Study contracts are not a panacea. Normally, or at least historically, this technique has been effectively applied to situations in which follow-on production is available as an incentive for participation in the study contract. It usually lengthens, to a marked degree, the time required to complete a complex development project and therefore would not fit a situation such as Mercury where time is of the essence.

3. NASA should retain in-house the detailed design, fabrication, assembly, test and check-out elements of a single advanced launch vehicle and space craft unique to each major program.** This would mean that at any given time JPL would be developing only one interplanetary spacecraft in-house; Marshall, only one launch vehicle or one stage of a multi-stage vehicle such as Saturn; and Goddard, one or more satellites depending upon the extent the scientific satellite, satellite application, and manned space flight programs presented unique spacecraft requirements. The selection of in-house subsystems should be accomplished in such a manner that NASA has within its total resources the understanding necessary to develop complete advanced space flight systems. The space vehicle subsystems selected should be ones that extend the state of the art in several interrelated areas - e.g., structure, propulsion, and guidance.

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* - Reflect in final draft plans being developed by OLVP and possibly other elements of NASA to use study contracts.

** - Or stage in the case of a project such as the Saturn Launch Vehicle - i.e., the S-I stage.

As a further clarification of this particular guideline, all subsystems related to clearly foreseeable operating systems (e.g., Nimbus in the field of meteorology) should be contracted out at the earliest possible date in order to educate industry in the actual operation of the system.

Retention of these four closely interrelated elements - detailed design, fabrication, assembly, test and check out - for a relatively few subsystems will serve to maintain the other in-house technical capabilities that are required to:

(a) Plan the NASA program and select missions effectively.

(b) Generate realistic requirements as a basis for the submission of contractor proposals.

(c) Develop realistic cost and budget estimates.

(d) Provide competent technical direction and supervision of contractor efforts.

4. Each center should contract out the detailed design, fabrication, assembly, test and check-out elements of all launch vehicles and spacecraft except the relatively few required to meet the criteria set forth in item 3 above. This will mean that NASA will depend to a much greater degree, in the future, on industry to schedule, coordinate, and physically integrate complete space vehicle subsystems, including all the necessary components, whether developed or acquired by the contractor, or developed by other contractors and furnished to the prime contractor by NASA. Contracting for total space vehicle subsystems (e.g., the Nimbus spacecraft) will (a) relieve NASA of the need for developing numerous schedules and sub-schedules for components and the attendant control mechanisms and (b) identify single focal points within industry for integration of spacecraft subsystems and the spacecraft with the launch vehicle.

The only exception to this criterion that may be required is in those cases where the element of the project (e.g., testing, checking, and launching) requires the use of unique and expensive facilities which are presently owned and operated by NASA and which should be available on the basis of "equal opportunity" for private and public agencies.

5. NASA's centers should contract all production manufacturing efforts including the standard or relatively standard parts and components used for in-house launch vehicles and spacecraft of an advanced developmental nature. All space vehicle subsystems subsequent to a limited number of items developed in-house in accordance with criterion 3 above should be produced and assembled by contractors. For example, in the case of the Saturn first stage, the first eleven prototype vehicles (C-1) would be done in-house and all of the balance (all operational vehicles) would be produced and assembled by private contractors. This will:

(a) Leave the limited in-house capabilities to work on selected subsystems that advance the state of the art and for technical supervision of contractor efforts.

(b) Utilize the resources best suited for production manufacturing - i.e., the large and qualified firms in this industry.

6. NASA should contract out total space vehicles, including the physical integration of subsystems - i.e., the launch vehicle and the spacecraft. Over a period of time, this will provide U. S. industrial firms with the experience that will be required to fully exploit such commercial applications of space technology as may develop. More importantly, this will provide NASA the industrial support that will be required to successfully carry out a program of the magnitude now contemplated, including systems engineering and the systems integration jobs - the two areas where NASA's abilities are relatively limited in relationship to the size of the program contemplated over the next ten years.

This guideline envisages the use of two possible approaches to contracting:

(a) Selecting a prime contractor to develop a particular spacecraft and integrating the spacecraft with the launch vehicle within technical parameters established by NASA. Under this approach the prime contractor would develop and install much, if not all, of the required instrumentation to carry out NASA-approved experiments.

(b) Selecting several "associate contractors", as in the case of Nimbus, to develop the various spacecraft subsystems and components, along with the use of a systems integration contractor to assemble the various spacecraft subsystems, and mate the spacecraft with a standard launch vehicle.

For the immediate future, the latter approach may offer substantial advantages over the former due to lack of industrial concerns who possess the requisite across-the-board capabilities required to handle effectively the development of a total space vehicle.

Under either contracting approach, it is assumed that conceiving the actual experiment to be undertaken, including the measurements to be made and data to be gathered, would, for the most part, still be the responsibility of university scientists.

Industry should not be given contracts for space vehicles unless it is also given the necessary control over the various space vehicle subsystems required to successfully accomplish the assignment. For example, the Space Technology Laboratory has sufficient control over all elements of an Able V experiment to permit them to carry out their assignment. However, in the case of a space vehicle employing the Saturn launch vehicle, it will not be possible to give industry responsibility for a total space vehicle until such time as the launch vehicle is past the development phase. To attempt to do so earlier would require placing elements of the Marshall Space Flight Center under the supervision of an industrial contractor.

7. <u>NASA should contract with the external scientific community a preponderant proportion (70-85 percent) of all space flight experiments.</u> NASA should retain in-house a sufficient number of experiments to maintain the interest and capabilities of a scientific staff to work with outside experimenters, principally university experimenters on the one hand and contractor personnel developing the spacecraft, on the other.

Involved in this criterion is the concept that most of the experimental instrumentation will be developed by industry directly for NASA or through contracts awarded by the institution responsible for the particular experiment.

Because of the substantial electronic back-up required to carry out space flight experiments successfully, many universities cannot provide the required supporting facilities and staffs. NASA, in cooperation with universities and other private institutions, must find ways of overcoming this problem by either (a) providing additional opportunities for members of the external scientific community to work in NASA space flight centers or (b) providing facilities and supporting personnel on a regional basis at a private institution for the joint use of others.

In summary, these criteria as to the division of work between NASA and private contractors:

1. Provide a realistic accommodation of the basic factors that must be considered - e.g., the amount and type of in-house capabilities that NASA has inherited and the desirability of enlisting private industry and the universities extensively in all elements of the space program.

2. Are essential to attract and hold able and well-trained men and with the needed scientific and technical skills to carry out NASA's Ten Year Plan.

3. Constitute a logical next step in the development of more precise guides to substitute for the informal criteria* that now obtain within NASA as to what should be done in the Space Flight Centers and what should be contracted out to private contractors. In this respect, it should be kept in mind that the intent of the present Space Flight Center concepts has been and is that of retaining in-house the minimum amount of capability required to achieve effectively the Space program through private resources - not to be able to do any element of the program in-house _per se_.

Our analysis of selected projects indicates that NASA has made substantial progress in the directions suggested by the above criteria. At JPL substantial elements of the lunar program including preliminary and conceptual design elements of total spacecraft are in the process of being contracted out. Three of the four projects reviewed at the Goddard Space Flight Center - magnetometer probe p-14, Mercury, Orbiting Astronomical Observatory, and Solar Spectroscopy S-16 - involve contracting out

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* - See page 2 - 9 of this chapter for a statement of criteria.

major space vehicle subsystems to industrial contractors and the majority of experiments to universities - 10 to 12 in the four projects studied. However, in each of the Goddard projects some elements of each project were being performed in-house - e.g., conceptual design, preliminary design backup, and check out and test of prototype components. In the case of Marshall, the first stage of Saturn is almost wholly an in-house effort, with the upper stages being contracted out.

Application of the above criteria to future projects at Goddard and Marshall will require contracting out substantially more, particularly in terms of complete space vehicle subsystems. This is necessary, not only to get these projects done but to provide that the limited in-house capabilities are used to their best advantage; that is, Goddard on advanced space experiments, including some of the experimental instruments, and Marshall on the systems of the future - i.e., those employing launch systems of the Saturn - Rover, Nova, and beyond class.

The criteria previously recommended should be promulgated both internally and externally as basic policies of NASA from which deviations are knowingly made. The issuance of these basic policies will not remove the necessity of the agency's top management from continually reconciling these criteria with (a) the rapidly changing nature and magnitude of various space flight programs and (b) the personal preferences of many of NASA's key staff members - scientific, technical, and administrative personnel.

USE OF RESEARCH CENTERS IN DEVELOPMENT CONTRACTING

Adherence to the division of effort suggested above, plus a reasonable transition period, should markedly increase the capabilities of the three Space Flight Centers to manage effectively the increased efforts involved in carrying out NASA's Ten Year Plan. However, there is substantial evidence to indicate that the Ten Year Plan cannot be achieved without some limited use of the Advanced Research Centers to provide the necessary technical supervision of development contracts for which their capabilities and experience especially fit them. Two alternative methods of using the Advanced Research Centers in the technical supervision of research and development contracts have been proposed: (1) placing project responsibility for limited projects in the centers themselves and (2) parallel project offices reporting to the offices of Space Flight and Launch Vehicle Programs.

An analysis of the implications of these two alternatives indicates that either the limited project responsibility or the parallel project offices is feasible without serious impact on the research work of the centers. Of the two alternatives, we recommend that NASA follow the practice of placing responsibility for limited projects in the Centers.

Establishing project offices in the Research Centers will make it possible to assign such contracts as those involving nuclear rocket research and development to the Lewis Research Center. This Center has a considerably larger in-house capability than the Marshall Center where it was originally proposed to assign supervision of nuclear rocket research and development contracts - five man-years as contrasted to approximately 120.

Another step that NASA can take to expand its capabilities to supervise contractor operations effectively is to view NASA's total resources in relationship to project management requirements rather than trying to achieve "center self-sufficiency". In other words, if a given scientific or technical competence exists anywhere within the Advanced Research and Space Flight Centers, it should be used in an advisory and consultative role by the various center project management teams wherever they may be located. There is nothing in the criteria set forth previously that implies that the required technical capabilities must be in the <u>same</u> laboratory environment in which a particular project management team may be located.

Methods must be developed to bring the resources of the Advanced Research Centers into full focus in preparing development plans for space flight and launch vehicle projects. This should be done in terms not of hardware development but of the contributions these centers can make through the advanced research they are conducting - or by more closely orienting the advanced research efforts of the centers around the problems that launch vehicle and space flight projects will encounter in the years ahead.

To make this criterion effective will require improved machinery for keeping all centers and certain key headquarters staff informed of the technical capabilities, staff resources, center workloads, status of advanced research, and similar matters than is presently the case.

USING SELECTED TECHNIQUES TO ENCOURAGE CREATIVE PARTICIPATION

As pointed out previously, private contractors have been used extensively on every major element of a project with the exception of conceptual and preliminary design, and steps are now under way to provide industry additional opportunities to participate in these elements of space flight and launch vehicle projects. Private resources have been enlisted to develop advanced chemical propulsion systems, all launch vehicles with the exception of the first stage of the Saturn, guidance and control systems spacecraft, instrumentation for payloads, advanced components, tracking and communication systems, data reduction, data analysis and such related services as reliability analysis. In addition, NASA is following, in general, the practice of contracting for total launch vehicle and spacecraft subsystems which require a high degree of technical problem solving and creative effort on the part of the contractor - e.g., the Mercury capsule, Orbiting Astronomical Observatory, the Orbiting Geophysical Observatory, and the Scout launch vehicle.

In addition, NASA is using advanced development funds in such areas as nuclear and electrical propulsion systems* to ensure the creative participation of private resources in the civilian space program. It is planned to use these funds to maintain and increase private capabilities - unrelated to development contracts of a production nature.

One additional technique to meet the basic and applied research needs of the Ten Year Plan should be given serious consideration. This would involve establishing unique and costly research facilities (e.g., various types of environmental test equipment, such as large, high vacuum chambers) on a regional basis with joint cost sharing with industry or full federal cost with associated universities as the actual operators and managers of the facilities. This would facilitate more extensive participation by university scientists in basic and supporting research related to space exploration. Informed observers believe a much more extensive underpinning of scientific research is absolutely necessary.

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* - This approach has also been employed in the case of plug nozzle development, liquid propulsion, and in lightweight nozzle work in solids.

ESTIMATING THE LEVEL OF IN-HOUSE CAPABILITIES REQUIRED

If the steps recommended here prove to be inadequate, it will then be necessary to raise the personnel ceilings that have been placed on the field centers, particularly those on the Space Flight Centers. The present personnel ceilings are necessarily arbitrary in that they were fixed on a gross basis rather than by being built up on a reasoned basis, element by element. However, there is substantial basis for believing that the imposition of these ceilings induced the Space Flight Centers to move quickly toward the use of private contractor capabilities.

No unerring formula can be used to estimate the total number of man-years required to carry out a given project in terms of (a) in-house supporting research, (b) development of in-house subsystems and components, (c) staffing of project management teams, (d) in-house technical advisory assistance to project management teams, and (e) technical and administrative support for each of these activities.

However, it would appear that NASA is arriving at a point where it can, with some hope of realism, develop reasonably, element by element, staffing requirements for the Space Flight Centers. Two of the basic tools appear to be near at hand: (1) a long-range plan - the Ten Year Plan continually revised in light of experience to date - and (2) a basic policy and related criteria as to the division of effort between NASA and private resources. Two related guidelines are discussed in the two following chapters: (1) requirements for project management personnel and (2) basic policies and guidelines to be followed in the technical supervision of contractors and in contract administration.

Application of the guidelines in each of these areas (and their general acceptance through NASA) should make it possible to develop estimates of in-house man-years required for each space flight development project along the activity breakdown mentioned above. Some additional experience may be required to determine the (a) ratios (or rules of thumb) that are applicable to supporting services and (b) minimum amount of time the various technical and scientific discipline groups must spend on actual in-house work to maintain their interests and skills.

A SUMMARY JUDGMENT

Analysis of the available data indicates, as a summary judgment, that:

1. NASA has made an increasing effort to "contract out" a substantial part of the work involved in the space program. However, industrial participation can advantageously be further increased by contracting out, as soon as practical, total space vehicles, including the physical integration of subsystems.

2. Private resources are being provided substantial opportunities to participate creatively in practically every element of the civilian space program with the exception of the preliminary and conceptual design elements. Additional steps are under way to broaden industrial participation in these elements of space flight and launch vehicle projects and in the area of advanced technology.

3. The present criteria as to what shall be done within the Space Flight Centers (page 2 - 9) and what shall be contracted out, it seems clear, are sound. They require, however, substantial clarification and reinforcement if they are to guide a staff (recruited within recent months from agencies where other policies prevailed) in making full utilization of all the non-governmental talents, skills, and facilities this nation can put to work on space exploration.

3 - ALLOCATION OF PROJECT MANAGEMENT RESPONSIBILITIES

The achievement of NASA's ultimate objective - the acquisition, analysis, and dissemination of data that will provide greater human understanding of space - rests on its capacity to conceive a succession of unprecedented experiments. Each experiment is dependent on the design and development of a launch vehicle and a spacecraft that will travel in outer space, observe, and record the phenomena found there. This development, known as a "space flight project", involves the precise technical interrelationship of the vehicle and the spacecraft, including the payload. The essentiality of integrating numerous components and subsystems into an articulated and exactly scheduled launching and subsequent recording of data is the uniquely complex cause of (a) organizational and (b) contracting problems for NASA.

The massive and complex character of the launch vehicles and spacecraft required in each space flight project makes inevitable the distribution of responsibility among several NASA centers and among industrial contractors. This distribution of responsibility, in turn, raises two central problems:

1. How should responsibilities be allocated for the resolution of technical problems that arise among the centers and industrial contractors in matching up one space vehicle subsystem with another, particularly the launch vehicle and the spacecraft?

2. How should project management responsibilities be allocated as between the headquarters and the field centers in order to provide a sound basis for the technical supervision and management of the various subsystems of a space flight project assigned to the centers and industrial contractors?

PRESENT ALLOCATION OF PROJECT RESPONSIBILITIES

Each of the present Space Flight Centers has had experience in the development of complete systems - JPL with Corporal and Sergeant; Goddard with Vanguard; Marshall with Redstone, Jupiter and the Argus Project. However, each center compared with the other centers has acquired more capability and interest in certain selected areas of space flight development and research than have the other centers - JPL in interplanetary projects, Marshall with launch vehicles, and Goddard with earth satellites.

To utilize as fully as possible these experiences, capabilities, and interests, the centers have been assigned the following over-all responsibilities:

> JPL has been assigned responsibility for Lunar and deep space unmanned exploration and research, including required tracking, data acquisition, data reduction, and analysis. Its responsibility also includes development of complete spacecraft, advanced spacecraft guidance and control, and advanced solid propellent and storable-liquid propellent upper-stage and spacecraft engines.
>
> Goddard is responsible for executing the sounding rocket, satellite and manned space flight programs. The Goddard Center is also responsible for the satellite and Mercury tracking, communications and data acquisition subsystems.
>
> Marshall is responsible for launch vehicle development, propulsion technology, launch vehicle technology, and the procurement and launching of space vehicles. In the conduct of a specific project (e.g., Ranger A) Marshall is responsible for the launching of the space vehicle through the point where the spacecraft is injected into a trajectory with the required velocity and accuracy.

In essence, this allocation of responsibilities means that two centers - Goddard and JPL - are primarily concerned with spacecraft, including the payload instrumentation. The third, Marshall, is primarily concerned with launch vehicles through the point of injection of the spacecraft with the required velocity and accuracy. This same fundamental divison of effort is carried into the organization of the headquarters staffs. The Office of Space Flight Programs is concerned with all spacecraft and thus is responsible for the general direction and supervision of the Goddard and JPL Centers. The Office of Launch Vehicle Programs is responsible for all launch vehicles and is therefore responsible for the general direction and supervision of the Marshall Space Flight Center.

This division of effort in the field and in the headquarters technical staffs, and the necessity of using common launch vehicles by Goddard and JPL creates what has been referred to as "NASA's built-in integration problem", a uniquely complex organizational problem. In other words, the present functional distribution of responsibility among the three Space Flight Centers - Goddard, JPL, and Marshall - does not effectively focus responsibility for the completion of a project in any center or individual short of the Associate Administrator in headquarters. In addition, the present distribution of responsibility, by its very nature, involves the headquarters staffs in the resolution of many "interface" problems that arise out of the fact that responsibilities for various space vehicle subsystems are distributed among two or more space flight centers.

This problem is not only of serious concern in terms of the effective internal management of NASA, but perhaps as importantly to the manner in which NASA conducts its relationships with subsystem contractors. Almost without exception the NASA contractors contacted during the course of this study commented adversely on the present diffusion of project responsibility as between headquarters and the space flight centers and among the centers.

ALTERNATIVE ARRANGEMENTS FOR ALLOCATION OF PROJECT RESPONSIBILITY

Five alternative arrangements for the fixing of responsibilities for project management have been proposed from time to time. These are not mutually exclusive.

1. Maintaining the present division of effort: The present method of handling the integration of various subsystems into a complete space vehicle required to carry out a project is depicted on page 3-5, "Technical Direction Channels for the Ranger A Project".* This organizational alternative depends heavily on interlocking center and headquarters technical coordination committees and panels to interrelate the efforts of two space flight centers that use the same launch vehicle to carry out different projects.

2. Assigning responsibility for the execution of each project to a given center: Many within NASA contend that the existing distribution of responsibilities among the centers is satisfactory, provided over-all responsibility for integration of the space vehicle subsystems required in each space flight project is assigned to a single space flight center. This would mean that over-all project responsibility would be fixed on the basis of the nature of the project.

For example, this might be achieved by (a) assigning all projects employing launch vehicles still in the development stage (Saturn and Centaur) to Marshall and (b) those projects employing a relatively proven launch vehicle (Agena B) would be assigned to the center responsible for the spacecraft.

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* - Distribution of Responsibilities in NASA Headquarters and Field Units for the Ranger A Project is set forth in detail in Appendix B.

Once over-all project responsibility is fixed in a single center, the center would rely directly on the responsive assistance of other centers and would be granted maximum freedom from headquarters in the resolution of technical problems which arise in matching up the various space vehicle subsystems.

3. Providing each center across-the-board project capability: Each of the three centers could be provided with across-the-board capabilities to integrate all the space vehicle subsystems required for a given program composed of several related space flight projects. This would mean in the case of the Lunar Program, which is assigned to JPL, that the Laboratory would be provided with capabilities to develop or monitor contractor development of launch vehicles, spacecraft, payloads, tracking, launching sites, including instrumentation, and means for data acquisition and analysis.

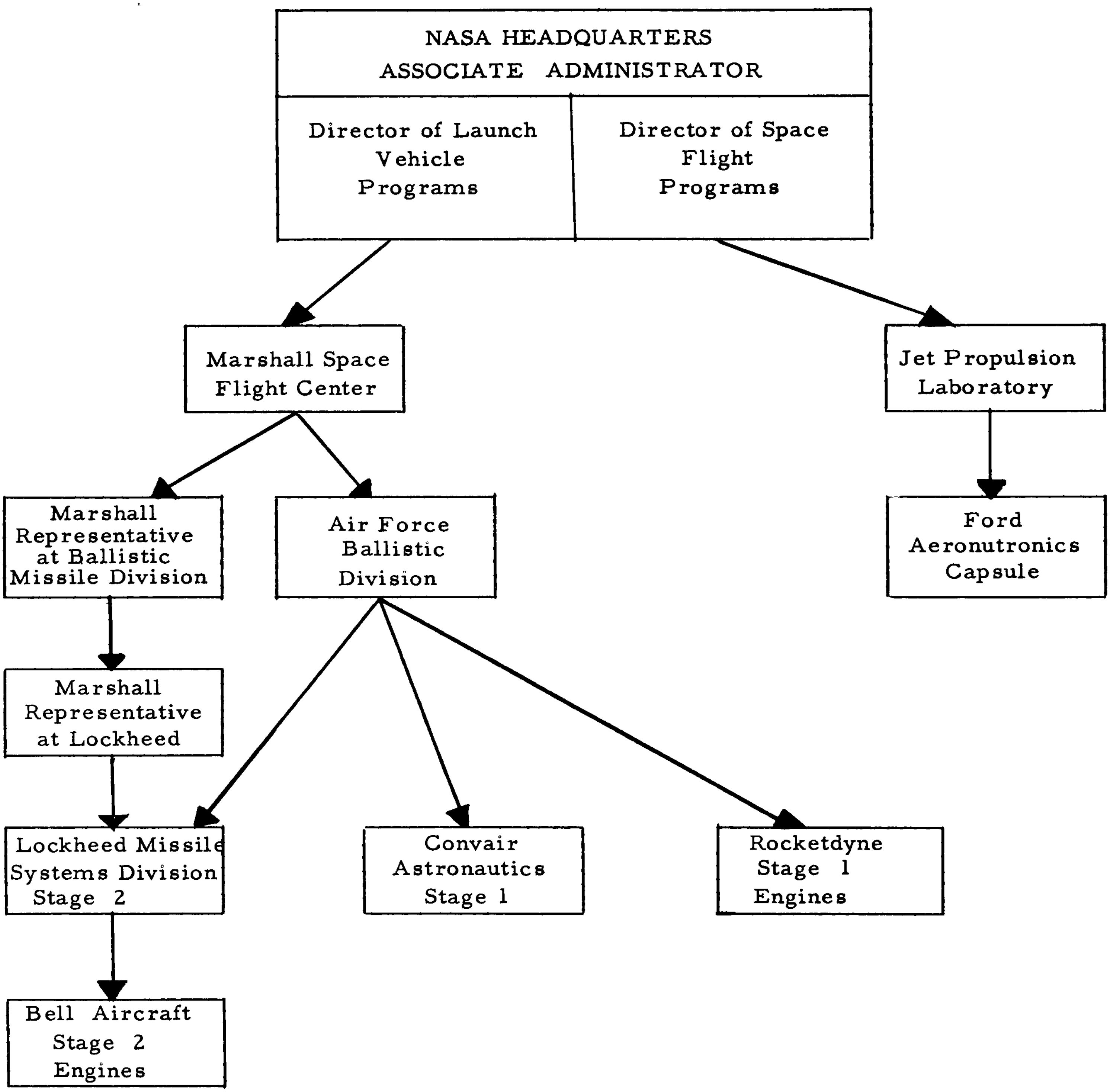
4. Assigning over-all responsibility for all projects to a single center: This alternative would involve making one of the three Space Flight Centers responsible for integration of all space flight subsystems - launch vehicle, spacecraft, launching facilities and tracking and ground communications for all space flight projects. The other centers would be responsible for either designing and developing, or procuring from private sources all instrumentation and apparatus necessary to conduct the particular experiments which fall within their present functional assignments - e.g., JPL for lunar exploration and research. This would be done after approval of the experiment, funding, and schedules by the headquarters staff.

5. Creating a new central project management organization: This alternative involves creating a separate "Systems Engineering Staff" in support of, or as an adjunct to, the headquarters technical staff. Under this alternative the headquarters staff would be responsible for over-all approval of conceptual design, scheduling and financing of each system; the continuing surveillance of the progress of the system; and the review and approval of any change in design or plans for execution which would significantly alter the objective to be accomplished, the time schedule, or the cost.

The "Systems Engineering Staff" would be responsible for converting general program plans into specific development and engineering tasks in a form suitable for sub-assignment to the centers and to industrial contractors. The current assignments of responsibilities to the centers are not considered to be inconsistent with the existence of a central system engineering organization.

TECHNICAL DIRECTION CHANNELS

FOR THE RANGER A PROJECT



(1) Within the scope of the contract only.

(2) Outside the scope of existing contracts.

The resulting arrangement would be similar to that employed by the Air Force in the development of ICBM systems, e.g., Atlas. In this case, the Air Force employs the Space Technology Laboratories, Inc., a private profit-making corporation, as the systems engineer and technical supervisor.

Each of the foregoing alternatives has been subjected to two kinds of analyses. First, each major element involved in developing a project (e.g., development of conceptual design) has been identified and a determination made as to where the responsibility for that element should logically be assigned under each alternative. This analysis is set forth in Appendix C.

Secondly, each alternative was analyzed against a list of basic criteria - e.g., does the alternative provide effectively for the multiple use of standard launch vehicles? These criteria were developed from a list of factors that would have to be accommodated in any workable plan. This analysis is set forth in Appendix D.

A RECOMMENDED SOLUTION

We recommend, on the basis of the analyses discussed above, that NASA:

1. Assign responsibility for the execution of each project to a given center. The assignment of a project would be based on conceptual and preliminary designs developed by one or more of the centers, or by a contractor. The center assigned over-all responsibility for a given project would be responsible for preparing a detailed development plan. This plan would recommend the allocation of responsibility for specific elements of the project to other NASA field centers - both space flight and advanced research centers - and to private contractors. This development plan would be reviewed and approved by NASA headquarters, including the limits within which modifications to standard launch vehicles could be made by the center assigned over-all project responsibility.

2. Determine the assignment of projects to the space flight centers in accordance with the following criteria:

   (a) Fix project responsibility in terms of the primary purpose of the project to NASA. If the primary purpose of the flights is to develop and test the Saturn C-2 launch vehicle, over-all direction should be assigned to the George Marshall Space Flight Center. If the purpose of the flight(s) is to fly by Venus, or to collect and return a Lunar sample, the over-all project responsibility should be assigned to the NASA space flight center which is responsible for the development of the fly-by spacecraft, or sample collection and return technique and hardware.

When off-the-shelf launch vehicles are used, or new launch vehicles that have completed the development stage, over-all project management responsibility should be fixed in the center with the greatest knowledge of the spacecraft involved in the project.

(b) Make maximum use of existing skills, facilities, and previous experience of each other.

(c) Minimize changes in the present distribution of responsibilities among the centers for on-going projects.

(d) Minimize the number of project management teams required in a center by retaining related projects in a given field in the same center, e.g., meteorological satellites at Goddard.

In summary, this solution to the problem of systems integration will (a) free up the limited headquarters staff for greater attention to program development and evaluation, (b) provide substantially more emphasis on converting general program plans into specific development and engineering tasks before they are assigned for execution, (c) fix responsibility for given projects, including actual integration of subsystems, (d) provide a basis for speeding up the making of technical decisions involving more than one space flight center, (e) clarify NASA - contractor working relationships, and give real meaning to the Administrator's announced desire to decentralize operations to the space flight centers.

Implementation of these recommendations will require (1) effective decentralization of project responsibility, both technical and administrative (e.g., contract negotiations and administration) to the centers, and (2) strengthening the project management capabilities in the centers. Each of these will be discussed in the last two sections of this chapter.

ACHIEVING EFFECTIVE DECENTRALIZATION TO THE FIELD CENTERS

The assignment of over-all project responsibility for each project to a field center will necessitate a clarification of the relative responsibilities of the headquarters staffs and the centers. Resolution of this problem requires immediate attention. To this end we recommend that responsibilities between NASA headquarters and the space flight centers be allocated in the manner set forth on page 3-9.

In summary, this means that the staffs in NASA headquarters, based upon submissions by the center assigned over-all project integrating responsibility, would review and approve:

1. A development plan, including conceptual and preliminary design, and allocation of responsibilities in- and out-of-house;

2. Schedules in terms of major procurement actions and technical milestones;

3. Budget justifications and financial operating plans.

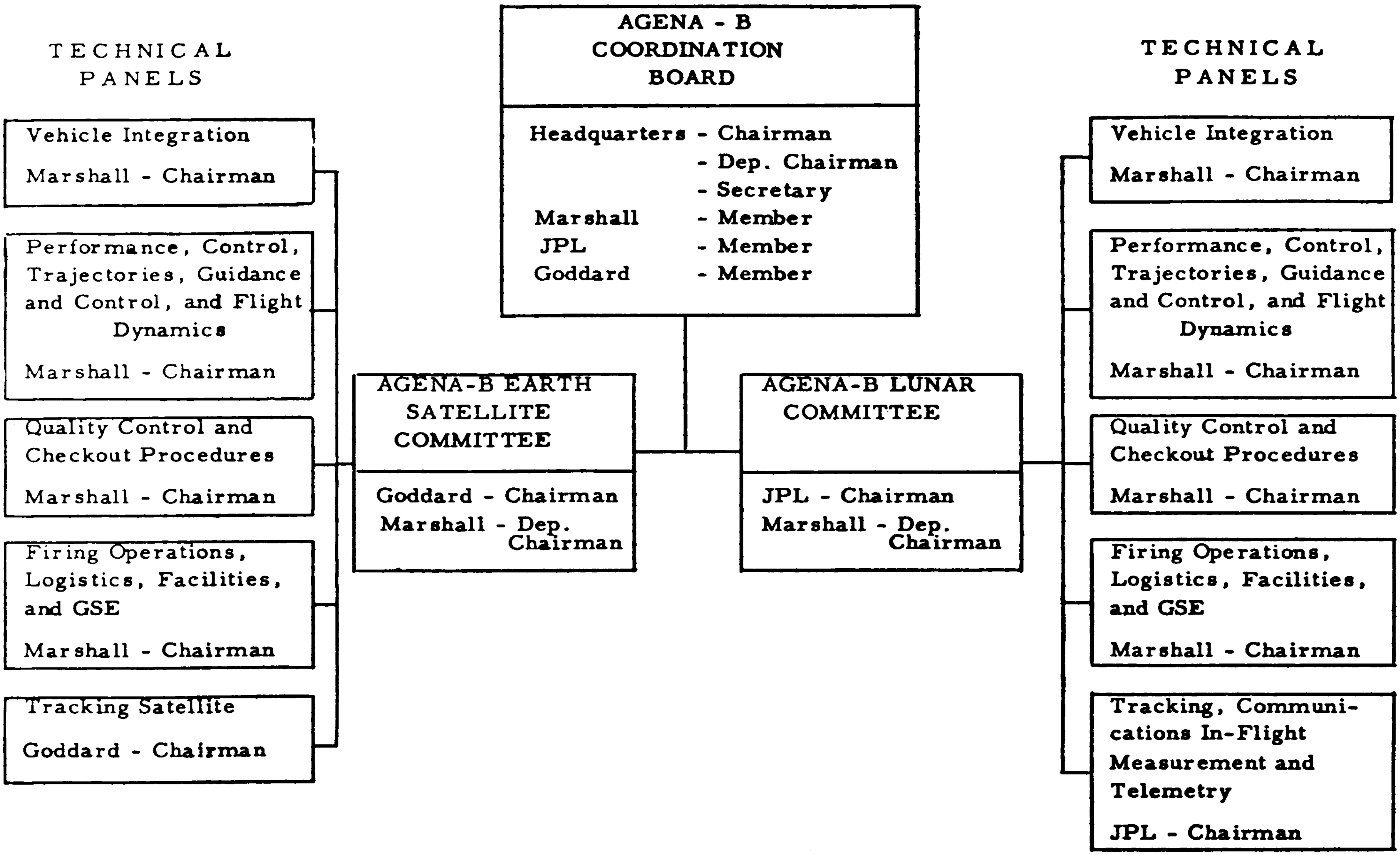
In addition, the headquarters staffs would evaluate projects and approve changes in the project plans which significantly alter objectives, schedules, and/or costs.

Technical or other conflicts that arise between the center assigned over-all project responsibility and supporting centers would be resolved in this manner: first, through the project manager and his counterparts in supporting centers; secondly, jointly with the Directors of the centers involved; thirdly, through the Directors of the centers with Directors of the headquarters program offices; and, finally, by the Associate Administrator. The interlocking headquarters-field coordinating committees (depicted on page 3-10) would be unnecessary and should be abolished. The project manager should have clear responsibility and authority to decide issues within the purview of his delegations, after which any unresolved issues should be settled in the manner indicated.

RECOMMENDED ALLOCATION OF RESPONSIBILITIES BETWEEN NASA HEADQUARTERS AND THE SPACE FLIGHT CENTERS

THE MAJOR ELEMENTS OF NASA'S JOB	HEADQUARTERS	SPACE FLIGHT CENTERS
1. Develop current and long range plans a. Identify over-all programs b. Identify program objectives c. Identify gross schedules d. Identify gross funding	Primarily a headquarters job with major participation of the Centers in terms of suggestions and recommendations	Suggestions and recommendations through formally established processes
2. Establish policies regarding intra-NASA and inter-agency cooperation and joint project participation	Primarily a headquarters function	Suggestions and recommendations as required
3. Establish broad agency-wide policies - e.g., standardization of components and reliability	Primarily a headquarters function	Suggestions and recommendations through formally established processes prior to approval by Administr'r
4. Develop specific projects (Systems engineering) a. Develop conceptual design	Assignment to a given Center with guidelines as to in-house or out-of-house	Develop or contract with industry
b. Develop preliminary design	Same as (a) above	Same as (a) above
c. Allocate supporting research, development, and fabricating responsibilities - both in-house and out-of-house	Guidelines to Center responsible for project, based on operating plan prepared by the Center to be assigned project management responsibility	Preparation of project development plan. Allocation of responsibilities both in-house and out-of-house in accordance with approved plan
d. Supervise technical responsibilities as allocated		By project manager in Center assigned project responsibility
e. Resolve technical questions arising from inter-relationship of sub-systems	By line officials in headquarters for technical interface problems involving common launch vehicles which exceed headquarters approved limitations on modifications	By project manager for assigned projects. If conflicts arise in use of common launch vehicles resolution through appropriate line officials
f. Test and evaluate	Review of test and evaluation plans as prepared by Center responsible for project management	Preparation of over-all test and evaluation plan by Center responsible for project. Supporting role by other Centers
g. Operate the system, including launching, data acquisition, data reduction, and data analysis		Launching by Marshall, Data acquisition, data reduction by Goddard or JPL depending on project. Data analysis by JPL, Goddard and/or private contractor. Over-all supervision by Center assigned proj. resp'y
5. Manage specific projects (Systems Management) a. Approve conceptual design	Approve design submitted by responsible Center	Develop or contract with industry
b. Schedule each system	Major milestones based on Center plan	Detailed schedules for various sub-systems involved in assigned projects
c. Finance each system (1) Formulate and justify budget	Prepare guidelines. Review of project submissions Justify before appropriate groups	Submission for total projects in accordance with HQ guidelines
(2) Control expenditures	Review and approve financial operating plans submitted by the responsible Center & review status periodically	Prepare financial operating plan for assigned project incl. all sub-systems & review status periodically
d. Evaluate progress	Review in terms of major project milestones	Review in terms of major sub-system milestones
e. Review and approve changes in design or plans which significantly alter objectives, schedules and/or costs	By headquarters for each project (See c and d above)	By responsible Center for assigned projects including all sub-systems prior to submission of project reports to headquarters

EXAMPLE OF PRESENT ARRANGEMENTS FOR ACHIEVING INTEGRATION
(Involving Use of the Agena-B Launch Vehicle)



STRENGTHENING THE PROJECT MANAGEMENT CAPABILITIES OF THE FIELD CENTERS

The capabilities of the space flight centers to manage effectively the large complex projects in which major subsystems or total space vehicles are developed by contractors require that NASA develop a group of outstanding project managers. On no other single group will so much of NASA's success or failure depend. Effective relationships with NASA headquarters, with the technical discipline and business elements of the center, with the project management elements of other supporting centers, and with contractors must come to focus in the project manager.

The total number of project managers required is not large - somewhere between 10 and 20. This estimate assumes that several of the smaller and less complex projects such as the S-15 gamma ray satellite can be supervised by a single project manager. In the last analysis the number of project managers actually required must be based on the analysis of the various projects in terms of dollar expenditures involved, technical complexity, number of contractors involved, and related factors.

In subsequent paragraphs we will discuss the (a) major responsibilities of the project manager, (b) organizational location of the project manager, (c) staffing of the project team, and (d) skills required on the part of the project manager.

(a) Responsibilities of the Project Manager

The success or failure of a given NASA project depends in substantial degree on the effectiveness with which the project manager in the center assigned over-all project responsibility:

1. Participates, at the earliest possible date, in the formulation of the objectives and systems engineering elements of the project, including the creation of the preliminary version of the development plan which sets forth recommended allocations of responsibilities among NASA centers and out-of-house.

2. Takes the leadership, in conjunction with the Director, and/or the Deputy Director of the center, in obtaining the approval of the project development plan by NASA headquarters.

3. Devises an organization structure and staffing plan for his own immediate office and a system of working relationships and organizational arrangements with other NASA centers that may be involved in the project.

4. Spells out and assigns, in consultation with the head of each major element of the center, the work to be carried out in-house, including the role each will play in the technical supervision of work to be executed by contractors. Also, in consultation with the management of other NASA centers, delineates their responsibilities and working relationships.

5. Evaluates, in conjunction with the technical and business management staffs of the center, contractors proposals, including the negotiation and resolution of matters requiring the approval of NASA headquarters.*

6. Revises and further refines the initial development plan for the project to include (a) schedules for completion of all critical elements of the system (including completion of supporting research), (b) financial operating plans, and (c) schedules of procurement actions. This will involve effective working relationships with the technical, financial management, and procurement staffs of his own center and with other centers involved in the project.

7. Establishes and operates a project scheduling, evaluation, and control system, including provisions for a continual flow of information to the program chief in NASA headquarters, to the technical and business management elements of the center, and to contractors.

8. Identifies critical problems in advance of their occurrence and adjusts plans and schedules in-house, among NASA centers, and with contractors.

9. Serves as a focal point for the coordination of relationships with contractors, technical personnel of the center, or other NASA centers, in the technical supervision of contractors.

10. Ensures that information is continually being fed back to the technical elements of the center responsible for systems engineering. As the

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* - This responsibility will have to be carried out in accordance with NASA's procurement regulations in such areas as source selection.

project is executed there is a continual need for refine the systems concept, cancel parallel or back-up efforts, and ensure that incremental advances in the state-of-the-art are reflected in the system. This requires that the systems engineering team or teams be continually and effectively related to the technical direction phases of bringing the system into being.

(b) Organizational Location of the Project Manager

NASA has not employed a consistent approach to the fixing of project management responsibilities. The arrangements made for each project have varied from highly decentralized arrangements* within the technical divisions that make up a given field center through the use of integrated project management teams.**

The steadily accumulating experience of industry, of private laboratories, and of NASA indicates that the management of complex research and development projects requires the focusing of responsibility in an integrated project management team. This team should be headed by a full-time project manager reporting directly to the Director or Deputy Director of the space flight center which is responsible for integration of the total system. This project management team should be distinct and apart from the discipline organization of the various laboratory technical units. Project management responsibilities associated with a complex system constitute a full-time job - as do division and section management jobs in a field center. In addition, the resolution of conflicts that inevitably arise requires a project manager who is in a position to have these conflicts resolved quickly by the Director or Deputy Director of the activity responsible for project integration.

(c) Staffing the Project Management Teams

These project management teams will have to be staffed with both technical and management personnel capable of working effectively with the technical personnel of the field center, other centers, contractor personnel (both technical and managerial), and NASA headquarters personnel.

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* - Examples include the first phase of the Scout vehicle development and P-14 (magnetometry probe).

** - As illustrated in the Saturn Systems Office at Marshall and, to a large extent, by the Space Task Group of Goddard in the case of the Mercury Project.

In the case of the less complex systems, the project manager should obtain staff assistance for the handling of financial and procurement problems from the offices responsible for these activities within the center. On projects of the size, complexity, and duration of Ranger A, Mercury, and the Orbiting Astronomical Observatory, however, he will require relatively few full-time personnel with these competences on the project management team. These personnel will have to be supplemented by full-time personnel competent to assist with scheduling, evaluation, and progress reporting. In addition, some technical personnel will be required on the project managers' staff to handle relationships with headquarters, center, and contractor technical personnel on such matters as the resolution of technical problems involved in systems integration, providing technical information on tests, and the need for revisions in system concepts, and similar matters.

(d) Skills Required in Project Managers

The need for project managers in the field centers is widely recognized in NASA. However, recognition of the skills required in project managers is considerably less well understood or appreciated.

Effective project management requires the availability of personnel who possess a combination of technical and managerial skills of a high order. A project manager must be skilled in the techniques of program planning, scheduling, reporting and evaluation - not only in technical terms, but also in terms of the financial, procurement, and other managerial aspects of project management. He must be one capable of drawing on the resources available within the technical, scientific, and business management elements of the center while vigorously limiting his own personal staff requirements. He must possess an objectivity that will allow him to perceive clearly the relative roles and importance of the contributions of the center, other centers, NASA headquarters, and contractors associated with the particular project.

To develop from within, or attract from without, the necessary project managers will require that NASA ensure potential candidates that:

1. They will be provided appropriate responsibilities, authorities, and organizational status, also, that these, in turn, will be recognized in terms of compensation and similar matters.

2. There will be a long-term need for persons possessing the requisite skills. This should be possible by phasing one project management team into a closely related follow-on project - e.g., this is being done in the case of the Space Task Group and the follow-on project to Mercury.

In addition, and importantly, the development of the requisite project managers must not be left to time and chance. The need is so substantial and immediate that NASA should launch a program for the development of the requisite skills in the individuals now serving in this capacity and their immediate assistants. The Project Manager's Seminar which NASA has initiated constitutes a promising step in this direction. The seminars should include both technical and management personnel involved in the management of NASA's major space flight and launch vehicle projects.

4 - CONTRACTOR SUPERVISION

The preceding chapter discussed the critical importance to NASA's success of the project manager. It emphasized the significance to NASA's internal operations of developing outstanding project managers and skilled project teams. This chapter examines NASA's external relationships with contractors. It deals in turn with:

1. Prerequisites to effective contractor supervision
2. Clarifying NASA's supervisory responsibilities
3. Guidelines for technical supervision
4. Guidelines for controlling costs
5. The use of other agencies.

PREREQUISITES TO EFFECTIVE CONTRACTOR SUPERVISION

Many aspects of NASA's structure and processes condition the manner and effectiveness with which it supervises its contractors. Some of these have been mentioned in previous chapters while others will be covered in Chapter 5. Here we are concerned with three items which are prerequisites to effective contractor supervision. In several instances, these elements of the contracting process have not been satisfactorily handled.

1. Adequate statements of work. Statements which define the work to be done with adequate precision (even while recognizedly difficult to prepare) are essential to provide a sound basis for evaluating contractor performance and to prevent costly delays during the course of a contract. Illustrations of contractual agreements which failed to meet this pragmatic test follow:

(a) The contract with McDonnell Aircraft Corporation for the Mercury capsule has produced several instances in which particular modifications in the project could not be clearly classified either as contract changes or as cost overruns. Such questions can place contractors in a difficult position with their subcontractors and often delay final disposition of contract change proposals.

(b) NASA's contract with Western Electric for the Mercury tracking system did not spell out the role of the Lincoln Laboratory as technical consultant. This resulted in confusion as to Lincoln's responsibility for performance rendered under the contract and its relationships with Western Electric.

(c) The F-1 engine contract with Rocketdyne deferred classification of certain items as either test equipment (which would entitle Rocketdyne to a fee), or as industrial facilities (which provide no fee). This postponement subsequently raised questions as to whether the fee had been waived and resulted in a compromise settlement not truly satisfactory to either party.

The essentiality of writing good work statements (i.e., decisive contractual agreements) is an important reason for maintaining in-house technical capability. NASA's difficulties in this area do not stem from any lack of this capability. Rather, they stem from the failure of the technical and procurement staffs to work together effectively and from the demands on procurement and legal staffs to prepare drafts of contracts without adequate time or sufficiently full consultation with the technical staffs. To ensure more adequate contractual agreements, we recommend:

(a) Development of a guide for preparing and evaluating statements of the work to be done and service to be rendered under research and development contracts. This should be the joint responsibility of the Office of Launch Vehicle Programs, the Office of Space Flight Programs, and the Procurement and Supply Division. Such a guide should set forth minimum information to be included. For instance, statements of work might include items such as those listed in Appendix E.

This guide must be supplemented by sound judgment to determine whether each individual work statement truly reflects those requirements the government wishes to place under contract. Such judgment requires close working relationships between procurement personnel and the technical officials generating the requirement - e.g., the participation of procurement personnel in preparing the work statement so that all areas which will improve the statement as a procurement instrument will be adequately covered.

(b) Devotion of more time to joint procurement planning by the technical and procurement staffs. This is required to ensure sufficient lead time for preparing statements of work for each project before contracts are let.

Preparation of work statements is, of course, only one element of the procurement process. Such planning, therefore, must provide adequate lead times for all critical elements - e.g., contractor submissions in response to proposal requests, source selection, and negotiation.

2. Sufficient and more flexible funding. Failure to fund a contract properly can necessitate the reprograming of important work or the postponement of work until the next fiscal year. For instance, funding difficulties contributed to the failure to approve any of nine contract change proposals on the Vega project. In addition, delays in providing sufficient funds for essential work agreed upon can result in contractors' starting work and making commitments before NASA makes money available. During the spring of 1960, for example, Western Electric had unfunded commitments of $1.5 million on the Mercury Tracking Project. In this instance the work progressed but the contractor was made to assume financial risks which were not properly his.

Avoidance of such difficulties will in most instances be achieved if time and attention is given to evaluating funding requirements before contractual commitments are made. Such evaluation will require full consideration of the complexity of the work, its priority, the technical unknowns involved, and related factors, and never can fully preclude the possibility of under-estimation. Hence, the persistent accumulation of cost experience on all contracts is important to the improvement of future estimates. To increase the value of this experience, we recommend that NASA:

(a) Require financial reports on all major cost-type contracts in order that it will obtain and may accumulate fuller and more revealing financial data from its contractors (the details of this recommendation are set forth in the subsequent section on controlling costs).

(b) Analyze its experience to date in estimating the funds required for key projects. This analysis should identify estimating problems and their underlying causes. It should also constitute the beginning of a continuing program to assemble and study cost data as a basis for improving future estimates.

The impossibility of estimating precisely the prospective funds required on many unprecedented projects that will be contracted for makes it essential that NASA seek ways of providing greater financial flexibility both within the scope of the contract and for contract changes.

(a) This flexibility could be achieved by segregating funds in original contracts for handling specific NASA study requests - e.g., on interface problems. For instance, the Agena-B contract reserves funds for performance studies, engineering liaison, physical parameter studies, and trajectory calculations requested or approved by NASA. Such funds allow more effective handling of NASA task directives by forming part of the initial cost base and, hence, eliminating the need for additional negotiations.

(b) Financial flexibility can also be achieved by allowing the contracting officer to approve work starts on contract changes up to prescribed cost ceilings before definitive costs are worked out. Ideally, changes should be completely "costed-out" before work is authorized. Every effort should be made to get contractors to commit themselves as soon as possible to cost quotations for which they will be held accountable. NASA's projects are of such a nature, however, that definitive costs may not be available within the limited time periods that project schedules can reasonably allow.

3. Focusing technical responsibility. A final prerequisite to more effective contractor supervision is the proper focusing of technical responsibility. For example, on the Delta Launch Vehicle, separating project management at headquarters from technical support at Goddard caused a triangular relationship with the Douglas Aircraft Company, Inc., which made contract changes more difficult to handle.

The Vega Project provides a further example of the need for clearly assigning the responsibility for technical supervision. On that project, although the authority for technical direction was assigned to JPL, direct contacts between headquarters and the Convair Division of the General Dynamics Corporation jeopardized the center's capacity to discharge its responsibility and made decisions difficult on such questions as (a) the site for shakedown tests and (b) the assignment of firing authority.

We recommend that NASA provide a single point of ultimate technical authority - i.e., the Project Manager - for each contractor on a given project. Accomplishment of this "focusing of technical authority" will be substantially assisted by assigning responsibility for the execution of each project to a given center.* In addition, NASA should:

(a) Channel technical commitments or indications of commitments through a single contractor contact point - e.g., the resident Project Engineer.

(b) Present a "NASA position" to contractors on technical questions by resolving internal differences of opinion within the agency. Exposing such differences to the contractor even for the purpose of obtaining his "informal" reaction can place him in an awkward situation and often makes the technical supervisor's position untenable.

(c) Refer contractors back to the individual assigned responsibility for technical direction if they attempt to circumvent this line of authority by direct contacts with other NASA units.

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* - See Chapter 3.

CLARIFYING NASA'S SUPERVISORY RESPONSIBILITIES

Progress toward the establishment of each of these three prerequisites (i.e., adequate statements of work, sufficient funding of contracts, and clear focusing of technical responsibility) will provide a sound basis for effective contractor supervision. On this foundation, improved practices of contractor supervision can be built. The building, however, requires understanding of the implications of two characteristics of NASA's procurement job.

1. The size of NASA's program and its expected growth require the extensive use of contractors. Further, NASA is beginning to contract for total subsystems which require a high degree of technical responsibility of and creative effort on the part of the contractor - e.g., the Mercury capsule and the upper stages of Saturn.*

2. NASA's program requires especially high standards of contractor performance. A high order of reliability must be achieved in the development of a small number of vehicle systems available to accomplish each mission.** Tight time schedules must be met. The job to be done is scientifically and technically complex.

The significance of these characteristics is clear. First, high contractor performance requirements indicate that a "trust the contractor" approach*** is not feasible. However, NASA's need to use contractors

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* - See Chapter 2, page 2 - 7.

** - For example, the Agena B Launch Vehicle is to be employed on 16 flights, all of which are one-vehicle missions except five lunar missions which are assigned two launch vehicles.

*** - Under this approach, final performance requirements are stated to the contractor and then his capabilities are relied on to deliver the required item. The chief advantage of this approach is that it tends to preserve the independence and initiative of the contractor. However, problems may not be discovered until performance standards, time schedules, or cost targets have been jeopardized. An example of this approach is NASA's F-1 engine project. In this instance, NASA defined ultimate performance requirements to be attained and contracted with North American's Rocketdyne Division for necessary research, development and management. Less than three full-time people were assigned to carry out technical supervision, with this staff supplemented through quarterly reviews by other technical personnel.

extensively suggests the importance of avoiding a "tight control" approach* which would discourage contractor creativity and initiative. In short, NASA must maintain sufficient control without stifling contractors' capabilities or relieving them of their obligations. Thus, NASA's primary role becomes one of guidance which shifts to contractor direction in appropriate situations. To perform this role, supervisory practices must:

1. Keep NASA informed at all times as to technical progress in relation to pre-set milestones and costs.
2. Ensure that ideas generated within NASA - e.g., through in-house research and development or through NASA-sponsored projects or studies - are used appropriately by contractors. In many situations, several approaches are possible and the NASA staff, because of its capabilities and experience, can frequently suggest faster and superior solutions.
3. Avoid in-house work that parallels contractor efforts except in special situations.
4. Give contractors maximum freedom in terms of day-to-day decisions as long as their over-all performance is satisfactory.
5. Ensure that NASA's staff will recognize significant contractor problems early.
6. Rely primarily on after-the-fact corrective measures which allow contractors opportunities to solve their own problems.
7. Permit NASA's staff to step in and handle problems, or otherwise direct the contractor when necessary.

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* - This approach relies heavily on in-house capabilities to detect and solve problems, influence contractor operations, and otherwise ensure the successful completion of a contract. It assumes that ways can be found to enable NASA's staff to detect impending difficulties and offer real assistance in either avoiding or solving such difficulties. Unless this approach is skillfully and tactfully followed, the contractor may become dependent to the extent that he (a) refuses to make a move without prior approval and (b) blames the government for trouble that arises. An example of this consequence is found in the Army's Sergeant Program. On that project, JPL maintained virtually a one-on-one engineer relationship with the contractor (Sperry Gyroscope Corporation), trained contractor personnel, and directed Sperry down to fine details.

The following sections of this chapter outline (a) general guidelines for discharging these supervisory responsibilities in the areas of technical supervision and cost control and (b) significant variations which may be required in applying general guidelines to individual situations.

In practice, contractor supervision may be affected by a number of factors - e.g., contractor capabilities, the complexity of the job, and priorities involved. The type of contract can also be important, particularly in the area of cost control. A number of NASA contracts, for example, will involve significant advances in the "state of the art". These technical unknowns will, in turn, require use of cost-plus-fixed-fee contracts which will make dollar incentives unavailable to help achieve performance standards.* In such situations, primary reliance will be placed on good supervision to ensure desired contractor performance in terms of time, quality, and cost.

On the other hand, some NASA procurements will involve items within the "state of the art" or will depend on achieving only nominal advances in the state of the art. In these instances, NASA should strive for fixed-price contracts. Thus, part of the burden of achieving a high level of technical performance and the control of costs is shifted to the contractor. For example, the Langley Research Center was able to use a fixed price contract with Chance-Vought for procurement of the airframe on the Scout Launch Vehicle.

GUIDELINES FOR TECHNICAL SUPERVISION

Our analysis of NASA's technical supervision revealed no significant problems. The reaction of contractors whose experience we studied was generally favorable. Special mention was made of: (1) the technical competence of NASA personnel and (2) the freedom allowed contractors to employ their own creative and problem-solving abilities. However, a need exists for guidelines as to the approaches and techniques to be used in technical supervision to ensure consistent supervision among the representatives from several centers, many of whom bring different backgrounds of experience to such assignments.

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* - See Appendix F entitled, An Analysis of NASA's Opportunities To Use Dollar Incentives in Procurements Involving Significant Advances in the State of the Art.

For example, JPL exercised extremely tight contractor control in the Sergeant Program. Similarly, Marshall's work on the Jupiter Program involved substantial in-house development, close contractor control, and complete in-house testing. Goddard's Vanguard group, in contrast, relied more heavily on contractor capabilities in developing the Vanguard satellite launch vehicle.

While guidelines must adapt to individual situations, we recommend these basic approaches and techniques to carry out NASA's responsibilities in technical supervision of contractors:

1. Use of meetings. Regularly scheduled meetings with contractor personnel should be held to review progress on each project and to exchange experience and suggestions. Such meetings should be "regularly scheduled" to ensure adequate time for advance preparation and should be planned to ensure systematic coverage of the entire project. Their frequency will necessarily vary in individual situations - e.g., quarterly meetings with Rocketdyne on the F-1 engine contract have proven satisfactory, while Langley has found it desirable to meet every six weeks with contractors on the Scout Project. We believe, however, that all contractor meetings should be used to the maximum:

(a) To bring together technical competence throughout the agency in an advisory and consultive role; in short, they should serve to make the "total resources" of the agency available to each project.

(b) To inform all contractors on a project as to the over-all status of the project and thus make each part of a team; the interdependence of subsystems that make up many projects makes such "team work" of large importance.

2. Assignment of in-plant representatives. A NASA representative in each contractor's plant should provide a single contact point to facilitate two-way communication. Such a representative would be available to assist the contractor in obtaining needed guidance and information. Simultaneously, such a representative should serve as the channel through which NASA's technical advice can be obtained and by means of which contacts between technicians of NASA and the contractor are facilitated - not obstructed.

In-plant representatives must be trained to minimize interference with contractors' operations by themselves or other NASA personnel. However, their authority should include (a) directing or authorizing shifts in or suspensions of work that are within the over-all scope of work and funds provided, (b) the technical interpretation of drawings and specifications, (c) the initiation of requests for data, and (d) the review of technical reports by the contractor.

3. Reviews of engineering drawings. Where a contract involves substantial design work as well as actual fabrication (as in many research and development procurements), the review of drawings by NASA staff members constitutes an important means for contractor supervision. These reviews should focus on (a) evaluating the contractor's general approach, (b) ensuring proper handling of interface problems, and (c) relating component and subsystem characteristics to the total project. They should not stress minute technical details.

In practice, the degree of detail necessarily involved in such reviews will depend on whether the drawings are for a complete subsystem or for an advanced component that NASA must technically integrate with many others. JPL, for example, may have to review drawings of components for in-house planetary spacecraft in much greater detail than those for the Centaur soft lander which will be contractor developed and which will require integration only with the launch vehicle.

4. Primary use of contractors for supporting research and development. In most situations, contractors should be allowed to do their own research and development at predetermined levels of effort in direct support of a contract. This (a) avoids diffusion of responsibility, (b) helps develop contractor capabilities, and (c) facilitates more ready contractor acceptance and application of ideas or products developed. Contractor efforts, however, may be supplemented by in-house research and development on problems with substantial technical unknowns and continuing applications.*

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* - For example, in-house research and development was done relative to heating problems on the Mercury capsule since the problem of over-heating has general application to all vehicles re-entering the earth's atmosphere. In contrast, no in-house work has been done on the problems connected with the F-1 engine combustion injector design because these problems are unique to the F-1's particular specifications.

5. Testing. In-house tests of contractor-developed products should avoid unnecessary duplications of contractor tests. The need for in-house testing should be carefully evaluated in each situation.

For instance, NASA may wish to enlarge the spectrum of tests to provide additional assurance of reliability - e.g., second-stage control motors for the Scout vehicle were tested by the contractor (the Walter Kidde Company) only at ground level conditions. Langley Research Center carried out additional altitude tests in a vacuum tank which uncovered flow problems resulting in a redesign of the motor chamber.

NASA's role with respect to contractor-conducted tests should be confined to:

(a) Ensuring that the contractor has an adequate testing program to prove the soundness of his designs and hardware

(b) Observance of tests rather than direction whether conducted with contractor or government facilities - e.g., Rocketdyne's use of NASA test stands at Edwards for F-1 engine tests

(c) The approval of test results.

* * *

Basic approaches and techniques to contractor supervision, as previously stated, must be tailored to meet conditions that obtain in individual situations. Conditions that will affect the approaches and techniques to be used are the contractor's capabilities, the complexity of the job, the relative priority to be attached to the job, and the performance observed on the job. Increased technical supervision based on any of these variables should be discussed with and understood by the contractor at the earliest possible date. Further, such extension of the supervision exercised by NASA's technical staff should ordinarily be confined to closer contractor coordination - e.g., to more frequent meetings to review progress and exchange ideas, rather than to more specific direction of a contractor's efforts, unless difficulties arise that the contractor cannot adequately handle. If such emergencies do arise, then NASA's staff must be prepared to:

1. Direct the contractor even to the point of substantially taking over.

2. Initiate a "back-up contract" - e.g., Aerojet was used to provide a back-up second stage motor for the Scout

vehicle when the original contractor - Thiokol Chemical Corporation - ran into grain-curing problems with a new solid propellent developed originally for the Air Force Minuteman Missile.

3. Re-award the entire contract. This step is an extreme action. It will be taken only as a last recourse because of (a) the money usually invested in the original contractor, (b) the experience developed by the original contractor, and (c) the reluctance of other contractors to take over in this kind of situation.

GUIDELINES FOR CONTROLLING COSTS

Our analysis of NASA's procurements suggests a similar need for guidelines as to staff action on the analysis and control of costs. Guidelines are needed as to (1) what analyses of prices, costs, and profits should be made prior to the award of a contract and (2) what techniques should be employed to control performance and costs subsequent to the award.

At present, there is little guidance available to inform NASA's staff as to (a) the types of cost analyses which should be made to appraise contractor proposals and (b) the controls which should be exercised over both prime contractors and subcontractors, including financial reporting requirements.* This lack has resulted in each NASA unit, both at headquarters and in the field, developing its own approach to cost control. For example, under the contracts with Bendix to maintain the Minitrack stations, no financial reports are required. Rocketdyne, on the other hand, under the contract for the F-1 engine, must submit monthly reports covering expenditures and commitments, including forecasts for the balance of the year.

(a) The Need for Means To Control Costs

The need for guidance in controlling costs is underscored by several aspects of NASA's procurement operation.

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* - NASA has recently drafted a "Proposed System for Financial Reporting by NASA Contractors Holding Cost-Type Contracts".

1. NASA's extensive use of cost-plus-fixed-fee contracts provides little or no incentives for the contractor vigorously to control costs. This lack of incentive to control costs is particularly significant when a contractor's staff and facilities are not fully utilized. When such a condition prevails, the contractor's desire to maintain across-the-board engineering capabilities likely causes the distribution of costly engineering hours against the volume of work on hand and, hence, a greater cost to the government.

2. NASA procurements with prime contractors involve substantial use of subcontracts - e.g., (a) roughly 75 percent of the dollars in NASA's contract with Western Electric for the Mercury Tracking System has been subcontracted, including major subcontracts with Bendix, IBM, and Burns and Roe, and (b) McDonnell Aircraft Corporation has made extensive use of subcontractors under the Mercury capsule contract (see Appendix G). NASA encourages the use of subcontracts as a means of distributing contract dollars to more firms. Their use, however, tends to reduce the agency's ability to control costs. At the same time, prime contractors often do not adequately control their subcontractors, especially when cost-plus-fixed-fee subcontracts are involved.

3. NASA's large dependence on the in-plant and other field staffs of the Department of Defense to administer its (NASA's) contracts is a further factor that makes direct cost control by NASA a difficult task.

(b) Price, Cost, and Profit Analysis

Under either (1) fixed price or (2) cost-plus contracts, there is need for revealing analyses of price, cost, and profit to aid NASA's technical and procurement staffs in determining whether a particular proposal is to the government's advantage.

In fixed price procurement, the immediate purpose of such analyses is to determine in advance the reasonable price. To do this, the analysis must include a review of (1) direct costs - e.g., materials and labor, (2) start-up costs - e.g., tooling and facilities, (3) overhead costs - e.g., factory overhead and depreciation, (4) general and administrative expense - e.g., selling expense, and (5) profits.

In cost-type procurement the ultimate goal is the same. The immediate purpose of such analyses, however, is threefold: (a) to assist responsible officials in selecting the contractor who will perform satisfactorily, (b) to establish the legitimate costs to be paid, and (c) to establish a reasonable profit or fee.

In carrying out these analyses, experience demonstrates the supervisory relationships between NASA and its contractors will be most effective if NASA strives to ensure that the contractor has sound internal controls and then permits the contractor maximum freedom of operations and record keeping within these controls. Adoption of this approach accentuates the importance of the initial analysis. To provide effective control, this analysis must include:

1. An evaluation of the contractor's accounting system. Under a cost-type contract, the contractor's actual costs are audited after contract completion. Therefore, the pre-award analysis must determine whether the contractor's cost accounting system is adequate to produce the information which will be needed.

2. An appraisal of the contractor's make or buy program - e.g., the effect on price of making a particular component, its relation to the contractor's normal in-plant operations, whether new facilities are required, and the capabilities existing elsewhere to make the same component.

3. An analysis of the contractor's purchasing policies and practices - e.g., the extent to which he examines his subcontractor's price proposals, whether he obtains complete cost and pricing data, how much competition he obtains, and how he controls subcontractor costs, especially on cost-plus-fixed-fee subcontracts.

Part of the price, cost, and profit analysis can usually be obtained through the cognizant military service. Such assistance, however, may require frequent supplementation - e.g., NASA may wish to have its own representatives (a) to interview contractor executives as to the management methods to be used on NASA contracts or (b) to survey the contractor's future business outlook and its possible effect on the costs NASA will likely assume under the contract.

(c) Post Award Controls

On cost-type contracts, in addition to the initial price, cost, and profit analysis, NASA should:

1. Periodically review the adequacy of contractor cost controls and their observance of these controls through "system audits". That is, NASA should conduct such audits as will satisfy it that the contractor's over-all arrangements (or "system") for forecasting and controlling costs give reasonable assurance of economical performance; it should not perform detailed audits of individual transactions.

NASA's present control in this area is limited by its extensive use of military audit services. However, relationships with military auditors can be strengthened. NASA can better satisfy its own needs for information as to contractor costs by: (a) developing and providing military auditors with NASA audit standards and (b) discussions between military auditors and NASA personnel to supplement written audit reports.

2. Require quarterly financial reports from all NASA contractors holding cost-type contracts over $100,000. These reports should reveal (a) costs for the current reporting period, (b) costs for the contract to date, and (c) projected costs to contract completion by quarter. To the extent possible, costs should be segregated by project element - e.g., design, fabrication and assembly, and testing, and by cost element - e.g., labor, overhead, procurement and fee.

These reports should be supplemented by monthly summaries of costs incurred during the reporting period and costs incurred to date.* Most importantly, financial reports must be effectively related to the progress of the project - e.g., to the agency's milestone reporting system.

To help achieve effective cost control on NASA contracts, both in the area of price, cost, and profit analysis and in the post-award controls, we recommend that the Headquarters Procurement and Supply Division undertake more effective training of procurement personnel in the field in the practices to be used. Such training should involve the preparation of written material and the exchange of experience among center personnel on such subjects as:

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* - This recommendation closely parallels NASA's "Proposed System for Financial Reporting by NASA Contractors Holding Cost-Type Contracts". Accordingly we recommend the early acceptance and implementation of this proposal.

1. Techniques to be used in evaluating cost proposals - e.g., evaluating manpower requirements to accomplish a job.

2. Techniques to be used in evaluating contractors' internal accounting and control systems.

3. The use of cost analyses to help verify the technical aspects of contractors' proposals.

4. The methods by which NASA's representatives can aid contractors in the control of costs.

5. The placement of restrictions on contractors to assure adequate cost control - the circumstances under which such action is required.

USE OF OTHER AGENCIES

Many NASA contractors are simultaneously performing under contracts with one or more of the military services. These contractors are, hence, being supervised by military representatives. For example, in ten of the twelve NASA projects analyzed*, the contractor is covered by the Department of Defense plant cognizance procurement program.**

This situation argues for continued use of the military services to assist NASA in carrying out its supervisory responsibilities. Such assistance avoids: (1) the duplicating expenditure of governmental manpower and funds and (2) the burden of dual supervision of contractors under different systems. The continued use of the military services to supervise contractors performing under NASA contracts, however, raises this question: To what extent and in what areas can NASA take advantage of this assistance and still maintain sufficient control over programs which differ in key characteristics from those of the military services?

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* - See Chapter 1, Table 1, page 1-7.

** - Under this program, responsibility for all procurement of aircraft engines, propellers, and airframes from certain commercial aviation plants is assigned to either the Air Force or the Navy.

To maintain adequate control, we recommend that NASA continue to:

1. Make its own source selections
2. Handle its own negotiations
3. Provide its own technical supervision.

NASA can control these essential elements by using the military services as procurement agents only in procurements involving items identical or similar to military requirements - e.g., Agena-B launch vehicles for use in NASA missions are modifications of the Air Force Agena-B launch vehicle. Such procurements will (a) not require source selection since NASA is merely adding on to an existing military contract and (b) still allow NASA's participation in negotiations and critical aspects of technical supervision - e.g., on Agena-B, NASA will work with the Air Force on negotiations and technically supervise vehicle modifications to meet NASA requirements.

We further recommend that NASA continue to use the military services for "field service functions"*, but that it supplement its delegation of these responsibilities by:

1. Periodic evaluation of the services received - e.g., in the audit area, this might include checks on the audit program, work papers, and results.
2. Direct handling when required in special situations.
3. Approval of major subcontracts. Approval of the subcontracts of NASA's industrial contractors is now largely delegated to the military services. Major subcontracts are referred to NASA for approval only

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* - NASA's agreement with the Air Force defines "field service functions" as including but not limited to: (1) contract administration (including price analysis), (2) security, (3) processing engineering change proposals, (4) property administration, (5) report reproduction, (6) inspection, test, and acceptance, (7) shipment, (8) termination and plant clearance, (9) contract auditing, and (10) priorities, allocations, and requirements.

on an informal basis. Some subcontracts are also reviewed in contractors' initial proposals - e.g., Western Electric included information on Bendix, Burns and Roe, and IBM as part of its proposal on the Mercury Tracking Project.

Because of the importance of subcontracts in its procurements, we recommend that NASA require the referral of subcontracts within clearly stated criteria. First, the Agency should review all subcontracts over a specified dollar value. To determine this value, NASA should study the subcontracts on its procurements to date to see what dollar level will cover the especially significant subcontracts without placing an undue burden on the contractor, the military representatives involved, or on NASA. Our examination of five NASA contracts* suggests that a level in the range of $100,000 to $150,000 is desirable. This dollar value must be supplemented by additional referral criteria based on the type and nature of the contract. For example, fixed-price contracts for material may be excluded regardless of dollar value. Conversely, time and materials contracts may be referred at a considerably lower dollar level. Finally, NASA may wish to review subcontracts for complex components regardless of the dollars involved.

In reviewing these subcontracts, NASA officials should focus their attention on (1) the source selection and (2) the adequacy of the statement of work to be performed by the subcontractor. The military services should continue to do the cost analysis and the review of contract terms. NASA's review of subcontracts (a) will provide additional opportunities to examine contractors' observance of their internal controls and (b) will permit the analysis of the contractor's action when subcontractors are entrusted with responsibility for critical components involving complex technical problems - e.g., on the Mercury capsule. When subcontracts involve such critical components, it is important that NASA's technical and procurement officials be aware of the dependence being placed on a subcontractor.

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* - Mercury Capsule, Mercury Tracking, Scout First Stage, Tiros II, F-1 Engine.

5 - STRENGTHENING NASA'S ABILITY TO CONTRACT EFFECTIVELY

DISSECTING THE WHOLE PROCUREMENT FUNCTION

Nearly two years' experience has demonstrated the large importance of NASA's procurement function and the vast difference in the size and character of this function as compared to the procurement function of NACA.

Viewed as a whole, this procurement function extends from the doing or contracting for the basic research that leads to the conception of a project, through the planning of its development, arranging for specific buys, contract negotiation, contract administration, to the completion of the launch vehicle, spacecraft, space vehicle, or component. It claims the attention of officials at every level of NASA's organization:

- The Administrator must participate in major source selections.
- His top staff, e.g., the General Counsel, must advise on the legality of procurement actions.
- The Associate Administrator must coordinate technical, financial, and administrative efforts.
- The headquarters technical staffs formulate specific "buy" decisions.
- The Business Administration staff must plan contracting procedures, carry out procurement actions, and supervise the performance of procurement activities throughout the field centers.
- Field center personnel at every echelon are involved in technical supervision and contract administration.*

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* - Approximately two-thirds of NASA's Fiscal Year 1960 procurement funds were used by the field centers.

The extensiveness and the involvement of technical and administrative personnel "up and down the agency" are characteristics of this function for which its organization must provide.

PROVIDING PROCUREMENT LEADERSHIP

NASA's effectiveness in contracting for the large volume and variety of goods and services it procures depends to a large degree upon the forging of efficient working relationships between technical and procurement elements at every level of organization. The responsibility for achieving this falls primarily on the Associate Administrator in his role of "General Manager" and, secondarily, on the Directors of the headquarters program offices and the Director of Business Administration. They must set the frame of reference for achieving effective working relationships between the technical and procurement staffs throughout NASA.

The principal medium available to the Associate Administrator and the Directors of the headquarters program offices to achieve effective contracting processes is the headquarters Procurement and Supply Division. This is the organizational element that (1) must provide the expert advice on contracting matters, (2) must work in cooperation with technical staffs at every level in devising effective contracting practices, (3) must carry out successive procurements from the selection of a contractor through final compensation, and (4) must provide effective leadership to the field procurement staffs. This staff must not only devise and direct the carrying out of specific contracting procedures, but it must also be capable of being a full-fledged partner in the planning and management of NASA's programs and their component launch vehicle and space-flight projects.

The actual negotiation and administration of contracts should be carried out at the level that is responsible for their detailed direction and execution - i.e., the field center project manager. The headquarters Procurement and Supply Division must develop the procedures by which the procurement function is carried out in the centers, help in training the procurement staffs in these centers, and ensure that close coordination obtains between the procurement staffs at headquarters and in the field.

Generally, the Associate Administrator and the Directors of the headquarters program offices must rely upon the headquarters procurement staff to plan, direct, and assist them in coordinating NASA's over-all procurement and supply program. The major functions of this staff in performing this role are:

1. Formulating and issuing procurement regulations, policies, and procedures to be followed by all NASA activities.

2. Reviewing and approving selected contracts negotiated by field contracting officers to (a) assure that they conform to procurement regulations and (b) assure that contract terms are technically correct, reasonable, and reflect sound business judgment.

3. Working with NASA contractors on policy questions, basic agreements, and standard clauses involving two or more contracts with different NASA field centers.

4. Reviewing procurement management performance in the field to further determine compliance with policies and procedures, and to develop and direct steps for improving procurement activities - e.g., training programs designed to upgrade the procurement know-how of technical and administrative personnel.

5. Compiling and maintaining cost, financial, and statistical contract data on a NASA-wide basis to meet statutory and Congressional reporting requirements and to aid in policy formulation and management performance evaluation.

6. Working with the Division of Financial Management and the Office of Program Analysis and Control to ensure that an adequate flow of procurement, financial, and project data is available to the Associate Administrator and others for their management and control of operations.

7. Negotiating and administering those contracts directed from headquarters - e.g., from the offices of Public Information, Life Sciences, Technical Information, Program Planning, and Reliability and Systems Analysis.

8. Representing NASA on procurement matters before other Government agencies, such as Department of Defense, General Services Administration, and Small Business Administration, and ensuring compliance with agreements and laws relating NASA procurements with the functions of these agencies.

9. Representing NASA before various industrial associations to explain NASA procurement policies, e.g., financial reporting requirements, and support of basic research.

To properly perform these functions the headquarters Procurement and Supply Division requires people who are strongly program-oriented, while at the same time possessing outstanding experience in, and a clear understanding of, the contracting methods associated with complex research and development projects. The Director of Procurement and Supply must bring staff with this know-how together to form a unit that can provide expert procurement assistance and leadership to the whole NASA organization. He must do this in such a manner that close contact and understanding between technical and procurement personnel are developed at all levels.

To date, NASA has not effectively organized to perform the whole contracting function,and the needed procurement leadership has not been developed. In subsequent sections of this chapter we describe and analyze the major shortcomings, and recommend steps for improvement.

SHORTCOMINGS IN CONTRACTING PERFORMANCE

The deficiencies fall under three major headings:

1. The headquarters Procurement and Supply Division has not yet been effectively established and staffed.

2. NASA technical staffs have repeatedly manifested a lack of understanding of the whole contracting process.

3. The principle of integrating technical supervision and contract administration has been frequently negated.

(a) Strengthening the Headquarters Procurement and Supply Division

There is substantial doubt that the internal organization and staff of the headquarters Procurement and Supply Division are adequate for the job. The inadequacy of this staff is given by NASA officials as the reason that:

1. A complete set of procurement regulations to guide technical and management staffs has not been developed and issued, e.g., policies are lacking on "make or buy" decisions by contractors, and support of contractor's basic and supporting research. The job is not only one of issuing regulations, but one of progressively improving and supplementing them, and in reflecting changes made in the Armed Services Procurement and Federal Procurement Regulations.

2. The internal organization of the Division has not been effectively defined. Statements of responsibility and authority for the principal jobs within the Division have not been agreed to and issued.

3. The Director has been unable to devote adequate time to working with the headquarters technical staffs, heads of procurement activities in the seven field centers, and with procurement officials in other government agencies and industry.

His time has been consumed by a variety of activities of an internal division management nature for which adequate staff does not exist, including the channeling of procurement matters from the field centers to the appropriate branches of the Procurement and Supply Division.

We have reviewed the plans the Director of the Procurement and Supply Division has developed (a) to clarify the organizational structure of the Division and (b) to augment its staff. On the basis of this review we recommend that the following steps be taken promptly:

1. Approve the organizational plan depicted on the following page with the following modifications:

(a) Center all activities related to facilities planning and utilization in a separate division in the Office of Business Administration. The magnitude and complexity of NASA's facilities problems warrant establishment of a clearly identified organizational unit. The activities to be performed are related to the work of several divisions within the Office of Business Administration - not to the Procurement and Supply Division alone.

(b) Place activities related to small business in the Policies and Procedures Branch rather than in the Field Management Branch, as indicated in the accompanying exhibit. Analysis of the work to be done reveals that it is more closely related to the work of the former than of the latter branch.

(c) Develop a system of across-the-board reviews of field center procurement activities in which key personnel from each of the branches participate. This approach will provide all of the procurement skills that are necessary to conduct effective reviews of field procurement activities. In addition, it will serve to keep key personnel in each of the major areas of procurement in first-hand touch with field procurement problems, including the effectiveness of their own activities - e.g., impact of procurement regulations and statistical reporting requirements on the field centers.

In summary, we propose (a) the establishment of a separate facilities division in the Office of Business Administration and (b) the abolition of what is presently termed the "Field Installations Branch" in the Procurement and Supply Division.

2. Establish a position of Assistant Director. The person appointed to fill this position should be given primary responsibility for the day-to-day internal management of the Division, including the channeling of work from the field centers to the appropriate branches.

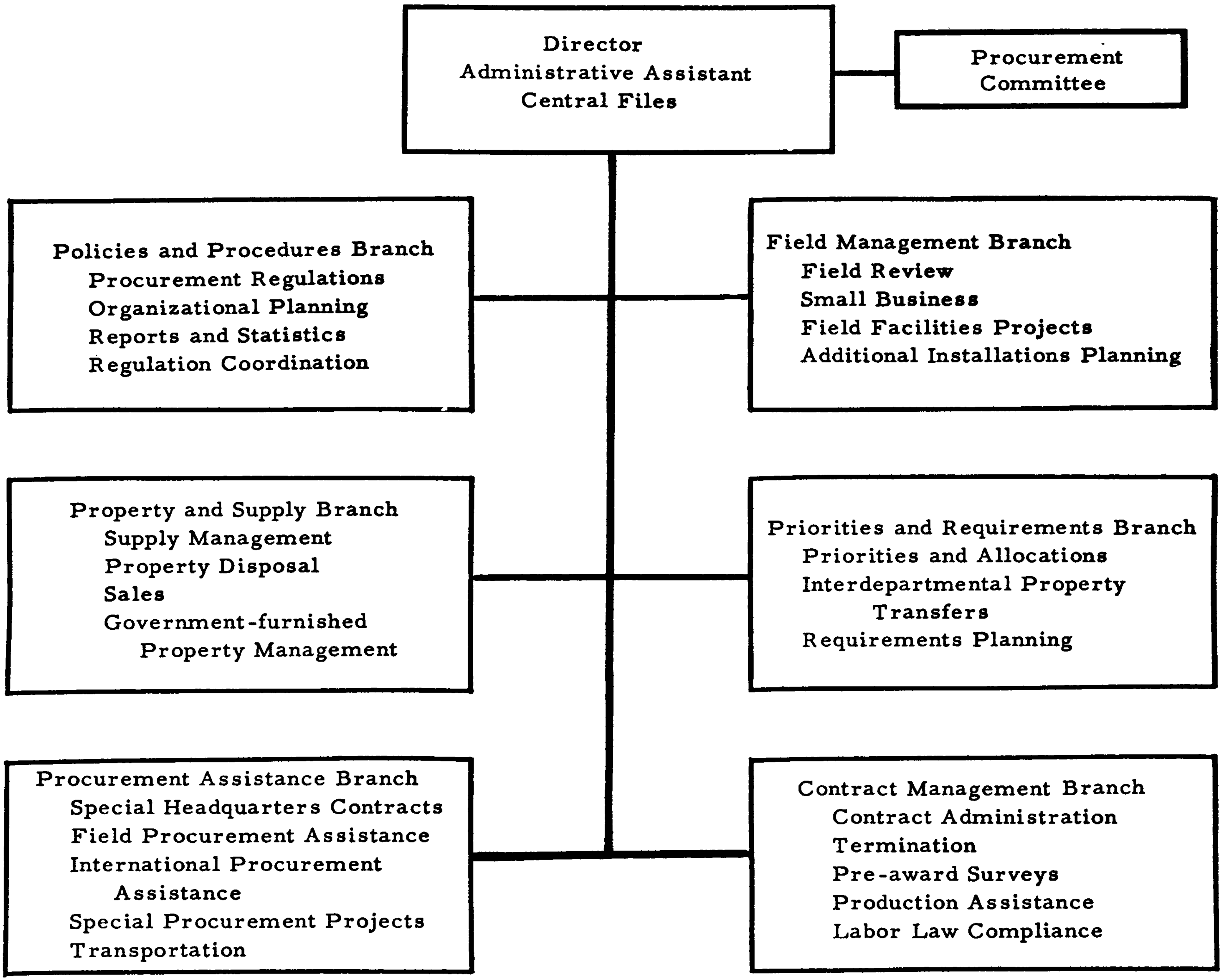
When the responsibility for internal management has been delegated to the Assistant Director, the Director should concentrate his attention on developing more effective working relationships with the Associate Administrator and the headquarters technical staffs, between technical staffs and procurement units in the field, and with other Federal agencies - e.g., Department of Defense, General Services Administration, and the President's Committee on Government Contracts.

3. Provide additional staff, particularly in the following areas:

(a) In the Policies and Procedures Branch, to effect the early issuance of a complete set of procurement regulations, covering such subjects as procurement by negotiation, pricing, support of contractor's research

PROPOSED ORGANIZATION OF

PROCUREMENT AND SUPPLY DIVISION



programs, and "make or buy" decisions; and to make regularly necessary revisions once a complete set of procurement regulations has been issued.

(b) For the Procurement Committee to provide effective and timely reviews of field procurement plans involving contracts in excess of five million dollars; pass on requests for deviations from standard contract provisions; and to perform the staff work related to the Director's authority from the Comptroller General to pass on mistakes alleged by bidders in formally advertised bids.

(c) In the Procurement Assistance Branch to handle the growing volume of headquarters procurement actions generated by the Offices of Public Information, Life Sciences, Technical Information, and Reliability and Systems Analysis.

Currently the Procurement and Supply Division has a staff of 36. Of this total 23 are professional employees and 13 are clerical. The Director of Procurement and Supply estimates that the minimum additional staff needed is approximately 20, of which 15 would be professional workers and 5 clerical workers.

The areas to which we have called particular attention above account for 14 of the 20 additional positions which it is estimated are needed. Our study of the Division indicates that the Director's estimate of the additional personnel required is reasonable.

In addition, our analyses confirm the opinion of some NASA officials that the headquarters procurement staff has not been given sufficient organizational status to enable it to carry out its responsibilities effectively.

The Associate Administrator, in providing over-all procurement leadership, may markedly assist in this by the manner in which he uses this staff. The recent appointment of the Director of Procurement as (1) chairman of the committee to review and evaluate source selection methods and (2) chairman of the committee to evaluate procurement plans involving contracts over $5 million represents an important step in this direction.

(b) Clarifying the Responsibilities of the Technical Staffs

Under the pressure to accomplish NASA's technical missions, the technical staffs have often attached insufficient importance to the actual contracting process. They have evidenced a lack of understanding of their responsibilities beyond the technical area and of the responsibilities of the procurement staffs for translating their needs into contracts with qualified suppliers. Expressions such as "there is no need for the analyses of prospective costs" - "all the procurement staff has to do is sign a piece of paper and audit some contractor's books" - are extreme reflections of the lack of understanding by technical staffs.

As a consequence of such lack of understanding, the technical staffs have:

1. Frequently set unrealistic time limits for procurement planning and negotiation - e.g., Saturn S-IV, an estimated $69 million contract that headquarters technical people wanted negotiated in two weeks' time; and Sunflower, on which negotiations were entered into so hastily that neither a proper statement of work nor a draft contract had been written - with resultant breakdown of negotiations and embarrassment to NASA.

2. Made contractual arrangements, agreements, and commitments independently of experienced contracting personnel. An example of such precipitate action is afforded by the handling of the solid rocket motor project, on which headquarters technical staff made specific cost and cost-sharing arrangements with a contractor, then directed the Goddard Space Flight Center procurement office to contract according to these arrangements. This and other examples demonstrate that NASA's technical staffs fail to recognize the need for coordinated effort between technical and business staffs on procurement matters, particularly those which involve cost-plus-fixed-fee contracts.

3. Often questioned the need for cost analysis and negotiation on CPFF contracts on the assumption that any and all costs are to be paid anyway. They often do not seem to recognize that all <u>reasonable</u> costs are to be paid and these must be determined by careful cost analysis. The fixed fee, of course, is based upon the reasonable costs so determined.

To overcome this lack of understanding of the contracting process evidenced by NASA technical staffs at headquarters and in the field, it is important that steps be taken to aid them in recognizing the:

1. Succession of actions that the procurement staff must take to negotiate and administer a contract, why these things must be done, and approximately how long they usually take.

2. Importance of keeping procurement staffs advised of actions or needs that will affect procurement actions.

3. Importance of recognizing what constitutes contractual commitments and refraining from making them without advice from NASA procurement staffs.

4. Importance of cost analysis and negotiation - and tolerance of the time it necessarily takes - as an essential and sound step in the business-like conduct of NASA's affairs.

There is no simple or established method for creating understanding and acceptance of these points by zealous technical people inexperienced in large-scale contracting matters. The primary obligation falls on NASA's management. It is to establish in day-to-day practice - at headquarters and in the field centers - the concept of team action in procurement matters. This concept should be clearly written into official policy statements. It should be continually emphasized in staff meetings, in training programs, and by such techniques as the issuance of a simplified contracting procedures handbook for ready reference use by technical personnel. Especially, the concept must underlie day-to-day actions on major projects (e.g., by repeated involvement of procurement staff members in discussions of the planning for technical projects that take place between the Administrator or Associate Administrator and the technical office directors and their associates).

(c) Integration of Technical Supervision and Contract Administration

A specific and critical area where the close integration of technical and procurement personnel must obtain is that of technical supervision and contract administration. This integration is essential since many of the decisions that have to be made in the contracting process, particularly research and development contracting, are neither purely technical nor managerial. For example, technical supervisors may direct contract changes that require additional funding, change the contractor's cost base and therefore his fee, generate new research efforts, and change both procurement and project milestones.

NASA contractors whom we interviewed were particularly emphatic in pointing out the need for integration of NASA's technical supervision and contract administration. They stressed the essentiality of being able to obtain the contracting actions required to implement technical decisions from the same authority - normally the project manager or a member of his immediate team.

NASA has demonstrated a lack of this important integration at both the headquarters and field levels. This shortcoming begins with the lack of joint planning that resulted in the pressure to allow inadequate procurement lead times - e.g., Saturn S-IV - and delays in providing contractual coverage - e. g., Sunflower. Principal reasons for this lack of integration are:

1. The failure of contract administrators to anticipate the needs of the technical staffs.

2. The failure of technical supervisors to keep contract administrators informed of technical changes.

3. The lack of essential communication between the technical supervisor and contract administrator responsible for a project - e. g., the Delta launch vehicle project manager was at headquarters and the contracting officer at Goddard, the Vega vehicle project manager at JPL and the contracting officer at headquarters.

This third problem area still exists to some degree in a number of contracts - e.g., advanced technology studies for the development of solid rocket motors are technically supervised from headquarters and administered by the Goddard procurement office. This situation was created when in December 1959, the Associate Administrator decentralized procurement activities to the field, but failed to remove technical supervision of contracts from headquarters.

The use of the Goddard Space Flight Center as a headquarters contracting office has not provided satisfactory service for the headquarters technical staffs. The additional burden of their requirements has slowed down the whole contracting process at Goddard, and several headquarters contracts, particularly those of the Office of Launch Vehicle Programs, have been delayed. As a result, pressure has recently been created to return contracting activities to headquarters.

In a very limited number of cases, it may be appropriate for NASA headquarters to award and supervise development contracts related to the development and feasibility of future programs.

However, it appears that most of the contracts now supervised from headquarters can be associated either with a specific project or with the specific skills of one of the field centers. These contracts should be technically supervised and administered from the field centers carrying out the projects and possessing the skills concerned. If the field centers are not thought to possess the requisite skills, then it is headquarters' responsibility to build up those skills in the field. This approach is consistent with NASA's avowed policy of decentralization. In view of this policy, and our recommendations on project management, we do not believe it advisable to re-establish a large contracting group at headquarters. In the final analysis, it is the role of the project manager in the field to integrate technical supervision and contract administration.

SUMMARY

In summary, our recommendations are focused upon three objectives:

1. Strengthening the headquarters Procurement and Supply Division.

2. Clarifying the contracting responsibilities of the technical staffs.

3. Integrating technical supervision and contract administration through effective project management in the field.

It should be emphasized that the responsibility for providing leadership to the whole procurement function rests with general management. General management's principal medium for effecting a successful procurement program is the headquarters procurement staff. Given the improvements recommended here, a more effective procurement function should be achieved.

DEFINITION OF TERMS USED IN "EVALUATION OF NASA'S CONTRACTING POLICIES, ORGANIZATION AND PERFORMANCE" *

1. Ten-Year Plan: This plan identifies specific NASA objectives to be reached during the next ten years. The guidelines for preparation of this plan are prepared by the Office of Program Planning and Evaluation. This Office is the focal point for coordinating and correlating the plans of all major elements of NASA.

2. Space Flight Program: An interrelated series of research and development projects designed to achieve NASA's major end objectives as set forth in the Ten-Year Plan. Current space flight programs include:

    (a) Application Program

    (b) Manned Space Flight Program

    (c) Lunar and Planetary Program

    (d) Scientific Satellite Program

    (e) Sounding Rocket Program.

    The over-all planning and responsibility of these programs rests with the Office of Space Flight Programs. Execution of all of these programs is assigned to the Goddard Space Flight Center with the exception of the Lunar and Planetary Program which is assigned to the Jet Propulsion Laboratory.

3. Space Flight Subprograms: Each Space Flight Program may consist of several subprograms. For example, the Applications Program consists of subprograms for meteorology, and communications; the Satellite Program subprograms such as astronomy and geophysics.

4. Launch Vehicle Program: The efforts related to the development of devices (launch vehicles) which will propel and guide space craft into orbit about the earth or into a trajectory to another celestial body, including all stages

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* - On October 14, 1960, NASA issued "A Staff Paper on Project Management" which defines some of the same terms contained in this Appendix, plus additional terms. Although the two sets of definitions vary in detail, it is believed that there are no major variations in the concepts involved.

of multistage rockets used for this purpose. The over-all planning and responsibility for the Launch Vehicle Program rests with the Office of Launch Vehicle Programs. Execution of the program rests with the George Marshall Space Flight Center with the exception of the Scout Launch Vehicle Project which is assigned to the Langley Research Center.

5. Space Flight Project: Consists of one or more space flight systems designed to accomplish a space flight experiment or series of experiments. For example, Project Ranger A consists of five launchings using the Agena B Launch Vehicle. These launchings include (a) two vehicle tests with instruments to measure cosmic radiation, magnetic fields, and hydrogen clouds, and (b) three lunar impact launchings.

6. Launch Vehicle Project: The efforts related to the development of a specific launch vehicle. Present launch vehicle projects include the Saturn, Centaur, Delta and Scout launch vehicles.

7. Spacecraft: Devices, manned and unmanned, designed to be placed into an orbit about the earth or into a trajectory to another celestial body, including all instrumentation, propulsion, and guidance contained therein.

8. Launch Vehicle: The device for launching spacecraft with the required accuracy, and velocity through the point of injection of the spacecraft.

9. Space Vehicle: The combination of spacecraft and launch vehicle.

10. Space Flight System: Consists of all the elements required to successfully operate a space vehicle. This normally includes four principal subsystems - launch vehicle, spacecraft, launching facilities, and communications, including tracking, telemetry, and ground communications.

11. Space Vehicle Subsystems: Each of the major elements that make up a space vehicle, i.e., the launch vehicle, spacecraft, launching facilities, and communications, including tracking, telemetry, and ground communications.

12. Launch Vehicle Subsystems: Include the structure, guidance, and control, and propulsion.

13. Spacecraft Subsystems: Include the structure, guidance, and control, and propulsion.

14. Components: Pieces of equipment that comprise various launch vehicle and space craft subsystems, e.g., pumps in the propulsion subsystem of a launch vehicle.

15. Conceptual Design: Determination of the basic parameters of configuration, size, cost, and performance of a space flight system, launch vehicle system or space craft.

16. Preliminary Design: Engineering design of systems, subsystems, and components from which definitive specifications can be developed for the detailed design required for actual construction fabrication, and physical integration of the subsystems and components involved.

17. Systems Engineering: Consists of those activities related to the original concept of a space flight system, the completion of the conceptual and preliminary design, the allocation and assignment of related responsibilities for the required supporting research and the development and fabrication of the system; the technical monitorship of the accomplishment of the allocated responsibilities; the resolution of all technical questions that arise in interrelating the work of those among whom responsibilities are distributed; and finally,the evaluation, testing, and acceptance of the system so produced.

18. Systems Management: Consists of those activities related to the adoption or approval of the conceptual design, scheduling and financing of each space flight system, including the scheduling of procurement actions; the continuing surveillance of the progress of the system; and the review and approval of any change in the design or plans for execution which would significantly alter the objective to be accomplished, the time schedule, or the cost.

19. Systems Integration: The actual physical "matching up" of subsystems, components, and parts to form a complete, operable, space vehicle and/or space flight system. This is done in accordance with system engineering requirements.

20. Project Manager: The individual in a Space Flight Center assigned overall direction and coordination of a particular Space Flight Project or a Launch Vehicle Project.

21. Chief of Program: The individual in headquarters who has staff responsibility for overseeing field center performance with respect to a project or a related group of projects that comprise a program or subprogram.

22. Basic Research: Research designed to produce the knowledge and develop the concepts for major technological advances in aeronautics and astronautics, e.g., theoretical and experimental research in the general area of high-temperature gas properties.

23. Applied Research: Research related to the solution of particular problems in specific hardware.

24. Space Flight Experiments: Research conducted through the use of instrumented space vehicles to (a) produce fundamental scientific data on the space environment, the sun, earth, and planets, and the galaxy; and (b) study potential applications of earth satellites to meteorological research and weather forecasting, long distance wide-band radio communication, navigation and similar objectives.

DISTRIBUTION OF RESPONSIBILITIES IN NASA HEADQUARTERS AND SPACE FLIGHT CENTERS FOR THE RANGER A PROJECT

PROJECT ELEMENT	NASA HEADQUARTERS			NASA SPACE FLIGHT CENTERS	
	OFFICE OF THE ADMINISTRATOR	OFFICE OF SPACE FLIGHT PROGRAMS	OFFICE OF LAUNCH VEHICLE PROGRAMS	JPL	MARSHALL
A. PLANNING Missions, Experiments, Experimenters, Funding, Schedules	1. The Administrator approves all missions, project budgets, and mission schedules. 2. The Administrator is cognizant of experiments and experimenters through staff briefings.	1. Works with JPL in selecting missions and coordinates with the Office of Launch Vehicle Programs on launch vehicle availability. 2. Makes final selection of experiments and experimenters with advice from JPL, Lunar Sciences Subcommittee, and Space Sciences Steering Committee. 3. Develops project budget with assistance of information received from JPL, and the Office of Launch Vehicle Programs. 4. Works with JPL to establish mission schedules and coordinates with the Office of Launch Vehicle Programs on required lead times to obtain launch vehicles.	1. Advises the Office of Space Flight Programs on launch vehicle availability, launch vehicle cost and required lead times for launch vehicles. This advice is given with the assistance of information received from Marshall.	1. Works with the Office of Space Flight Programs in selecting missions. 2. Makes recommendations to the Office of Space Flight Programs on experiments and experimenters and provides three members of the Lunar Sciences Subcommittee. 3. Provides spacecraft and payload cost data to the Office of Space Flight Programs. 4. Works with the Office of Space Flight Programs to establish mission schedules.	1. Provides data to the Office of Launch Vehicle Programs on launch vehicle availability, launch vehicle cost, and required lead times for launch vehicles.
B. IMPLEMENTATION Work statements, Cost Estimates, Proposal Requests, Proposal Evaluation, Source Selection, Contract Negotiation and Execution.	1. The Administrator made the final source selection for the lunar capsule contract.	1. Provided a member of the source selection board for the lunar capsule.	1. Initiated procurement requests for Atlas through July 1, 1960. After July 1, Marshall assumed this function. 2. Initiated the procurement request for the Agena B's with Goddard's procurement division handling the transfer of funds to the Air Force. 3. Participates in negotiations with Lockheed for Agena B vehicles.	1. Prepares work statements and cost estimates for the lunar capsule and components of the Ranger spacecraft. 2. Evaluates proposals for the lunar capsule and spacecraft components. 3. Negotiates and awards contracts for the lunar capsule and spacecraft components. 4. Executes contracts for payload experiments assigned to JPL for handling.	1. After July 1, 1960, initiates requests for Atlas and handles transfer of funds to the Air Force for Atlas procurements. 2. Participates in negotiations with Lockheed for Agena B vehicles.

DISTRIBUTION OF RESPONSIBILITIES IN NASA HEADQUARTERS AND SPACE FLIGHT CENTERS

FOR THE RANGER A PROJECT

PROJECT ELEMENTS	NASA HEADQUARTERS: OFFICE OF THE ADMINISTRATOR	NASA HEADQUARTERS: OFFICE OF SPACE FLIGHT PROGRAMS	NASA HEADQUARTERS: OFFICE OF LAUNCH VEHICLE PROGRAMS	NASA SPACE FLIGHT CENTERS: JPL	NASA SPACE FLIGHT CENTERS: MARSHALL
C. MANAGEMENT System Integration and Detailed Financial Plans and Schedules	1. The Associate Administrator resolves system integration problems which cannot be handled by the Directors of Space Flight and Launch Vehicle Programs.	1. The Director of Space Flight Programs resolves system integration problems which cannot be handled by the Agena B Coordination Board. 2. A representative of the Director of Space Flight Programs chairs the Agena B Coordination Board. 3. A representative of the Lunar and Planetary Programs Division serves as Secretary of the Agena B Coordination Board. 4. Disseminates policy and ensures that the system is consistent with NASA objectives and mission plans. 5. Approves detailed financial plans developed by JPL and ensures that missions are consistent with NASA's financial resources. 6. Maintains cognizance of spacecraft and payload schedules and approves any significant schedule changes.	1. The Director of Launch Vehicle Programs resolves system integration problems which cannot be solved by the Agena B Coordination Board. 2. A representative of the Vehicle Division serves as Deputy Chairman of the Agena B Coordination Board. 3. Disseminates policy and ensures that the system is consistent with NASA objectives and vehicle plans. 4. Approves detailed financial plans developed by Marshall and ensures that the vehicle program content is consistent with NASA's fiscal resources. 5. Maintains cognizance of launch vehicle schedules and approves any significant changes.	1. The Lunar Project Director serves on the Agena B Coordination Board and chairs the Lunar Committee. 2. JPL technical personnel chair the technical panel on tracking and serve on the other panels. 3. The JPL Director resolves system integration problems which cannot be handled by the Lunar Committee. 4. Takes action on system integration decisions of the technical panels related to the spacecraft and integrates the spacecraft, capsule, and all spacecraft instrumentation. 5. Provides Marshall with vehicle performance requirements -e.g., trajectory and accuracy. 6. Prepares detailed financial plans and schedules for the spacecraft and revises these plans and schedules as needed.	1. The Agena B Project Director serves on the Agena B Coordination Board and is Deputy Chairman of the Lunar Committee. 2. Marshall technical personnel serve on the tracking panel and chair the technical panels on vehicle integration, performance, quality control, and firing operations. 3. The Marshall Director resolves system integration problems which cannot be handled by the Lunar Committee. 4. Takes action on system integration decisions of the technical panels related to the launch vehicles. 5. Reworks JPL's vehicle performance requirements into engineering orders for contractors. 6. Prepares detailed financial plans and schedules for the launch vehicles and revises these plans and schedules as needed.
D. EXECUTION Design, Fabrication and Assembly of Subsystems and Components, Checkout of Prototype and Operating Units, Launch Operations, Data Acquisition and Analysis, and Report Preparation.	1. The Administrator or Associate Administrator approves project changes significantly affecting missions, cost, or schedules.	1. Ensures that spacecraft designs are consistent with objectives, compares progress with plans, and approves changes significantly affecting missions, costs, or schedules.	1. Ensures that vehicle designs are consistent with objectives, compares progress with plans, and approves changes significantly affecting missions, costs, or schedules.	1. Technically supervises design, fabrication, and assembly of the lunar capsule and scientific instruments. 2. Designs, fabricates and assembles the spacecraft and certain scientific instruments-e.g., electrostatic analyzers.	1. Approves Agena B designs and technically supervises Agena fabrication and assembly. 2. Monitors development of Atlas for Agena B lunar missions.

DISTRIBUTION OF RESPONSIBILITIES IN NASA HEADQUARTERS AND SPACE FLIGHT CENTERS

FOR THE RANGER A PROJECT

PROJECT ELEMENTS	NASA HEADQUARTERS			NASA SPACE FLIGHT CENTERS	
	OFFICE OF THE ADMINISTRATOR	OFFICE OF SPACE FLIGHT PROGRAMS	OFFICE OF LAUNCH VEHICLE PROGRAMS	JPL	MARSHALL
		2. Maintains cognizance over tracking plans, equipment and the tracking net. Assists in handling scheduling problems and handles relationships with the Department of Defense and foreign governments. 3. Ensures that test plans for spacecraft and its supporting and tracking equipment developed by JPL and contractors are consistent with project plans and objectives. 4. Ensures that spacecraft launch plans and operations, and spacecraft tracking plans are consistent with project plans and objectives. Provides coordinating services as needed. 5. Ensures that acquired spacecraft data are properly analyzed and disseminated.	2. Maintains cognizance over engine development - e.g., Bell Aircraft engines for the Agena B vehicle. 3. Assists in planning for and maintains cognizance over Agena facilities and support - e.g., range hangar, launch pads, and range tracking facilities. 4. Ensures that vehicle test plans developed by Marshall and contractors are consistent with project objectives and plans. 5. Ensures that vehicle launch plans, and launch operation plans including range tracking are consistent with project plans and objectives - provides coordinating services as needed. 6. Ensures that vehicle performance analysis is carried out and that the vehicle report is properly disseminated.	3. Assembles spacecraft check-out equipment, spacecraft launch complex equipment, and tracking equipment. 4. Helps develop and approves contractor test plans for the capsule. 5. Approves contractor test plans for spacecraft and equipment components, observes contractor tests, and conducts in-house tests required to ensure reliability. 6. Works with Lockheed to develop test plans for the spacecraft including compatability tests with the Agena. 7. Responsible for spacecraft tests at the Atlantic Missile Range including joint responsibility with Marshall for the joint composite test. 8. Has over-all responsibility for launching mission decisions, spacecraft preparation, and criteria n necessary for mission attainment. 9. Participates in launch operations to ensure mission readiness and performs the spacecraft countdown. 10. Tracks the spacecraft after injection and accumulates and analyzes spacecraft data. 11. Expedites scientific data to appropriate experimenters for analysis. 12. Prepares and distributes the spacecraft report.	3. Helps develop and approves vehicle contractor test plans, witnesses contractor tests, and conducts in-house tests on vehicles and vehicle components required to ensure reliability 4. Has over-all responsibility for vehicle tests at the Atlantic Missile Range and joint responsibility with JPL for the joint composite test. 5. Has over-all responsibility and authority for planning and executing the launch, and for AMR operations. 6. Has over-all responsibility for the conduct of the countdown. 7. Tracks through the injection phase and acquires and analyzes launch vehicle performance data. 8. Prepares and distributes the vehicle report.

ANALYSIS OF THE DISTRIBUTION OF SPACE FLIGHT PROJECT

RESPONSIBILITIES UNDER VARIOUS ALTERNATIVE PLANS

The Major Elements of NASA's Job	Present Distribution of the Major Elements of the Job		Assigning Responsibility by Individual Project to Specific Centers		Providing Each Center Across-the-Board Capability to Carry Out Complete Projects	
	Headquarters	Development Centers (Including JPL)	Headquarters	Development Centers	Headquarters	Development Centers
1. Development of a long-range plan. a. Identify over-all programs. b. Identify program objectives. c. Identify gross schedules. d. Identify gross funding.	Primarily HQ utilizing suggestions and recommendations from the Development Centers.	Suggestions and recommendations for HQ consideration.	Same as present.	Same as present.	Same as present.	Same as present.
2. Establish policies regarding intra-NASA and inter-agency liaison.	Primarily HQ	Suggestions and recommendations.	Same as present.	Same as present.	Same as present.	Same as present.
3. Establish broad agency-wide policies - e.g., reliability.	Primarily HQ.	Suggestions and recommendations.	Same as present.	Same as present.	Same as present.	Same as present.
4. Development of specific projects (Systems Engineering). a. Development of conceptual design.	Review by each functional office.	Prepare for assigned subsystems.	Review of integrated conceptual design as prepared.	Prepare for assigned subsystems and submit for integration by each center with project responsibility (Proj. Cen.)	Review over-all conceptual design proposal by each center for its assigned projects.	Prepare complete conceptual design for each assigned project.
b. Development of preliminary design.		Same as 4 a. above		Same as 4 a. above.		Prepare complete for each project.
c. Allocation of supporting research development and fabricating responsibilities - in-house and out-of-house.	Role of HQ varies markedly from project to project. In general, gross allocations are made by functional staffs for both in-house and out-of-house.	Sub-assignments are made by Development Centers within scope of HQ allocations of responsibility.	Allocation to the Development Center assigned the particular project with appropriate policy guideline.	Sub-assignments to "supporting" centers by each Project Center.	Allocation to each Development Center for assigned projects with appropriate policy guidelines.	Sub-assignments within each Center and to contractors in accord with HQ policy.
d. Technical supervision of allocated responsibilities.	Varies from project to project - over-all in HQ project manager.	Responsibility for assigned subsystem within the context of whatever project management structure that has been set up by HQ.		By Project Manager in Center assigned project responsibility (Project Center).		By Project Manager in each Center for assigned projects.
e. Resolution of technical questions arising from interrelationship of work.	Problems that cannot be resolved in Center Committees and technical panels come to HQ Coordinating Committees.	By technical panels and committees with interlocking membership at Center level (see Agena B chart).	By HQ for interface problems such as those involving common launch vehicles in which HQ modification parameters are exceeded.	Technical panels and Center Project Manager for assigned projects, who exercises directive authority over supporting Centers.		By individual Center for assigned projects.
f. Testing and evaluation.	Review of test and evaluation plans as proposed by various centers.	By Development Centers for assigned subsystems - prelaunch checkout by Launch Vehicle Center.	Review of the test plans of the Project Center.	Over-all test and evaluation plan by Project Center. Project Center and Supporting Centers carry out.	Review of test plans of responsible centers.	Preparation of test plans and conduct of tests.
g. Operating the system, including launching, data acquisition, data reduction, and data analysis.		Launching by Launch Vehicle Center. Data acquisition and reduction by GSFC or JPL depending on project. Data analysis by GSFC, JPL and/or contractor.		By the Project Center or one of the supporting centers at the direction of the Project Center.		All tasks by Center responsible for given projects.

ANALYSIS OF THE DISTRIBUTION OF SPACE FLIGHT PROJECT

RESPONSIBILITIES UNDER VARIOUS ALTERNATIVE PLANS

(Continued)

The Major Elements Of NASA's Job	Present Distribution of the Major Elements of the Job		Assigning Responsibility by Individual Project to Specific Centers		Providing Each Center Across-the-Board Capability to Carry Out Complete Projects	
	Headquarters	Development Centers (Including JPL)	Headquarters	Development Centers	Headquarters	Development Centers
5. Managing specific projects (Sys. Mgmt.) a. Approval of conceptual design	By HQ.		By HQ.	By Project Center prior to submission to HQ.	By HQ.	By Center for projects for which it has been assigned responsibility - prior to submission to HQ.
b. Scheduling each system.	Primarily major milestones - varies, however, with HQ involved in some detailed scheduling.	Detailed schedules for assigned subsystems.	Major milestones only.	Detailed schedules for subsystems involved in Center's project assignment.	Major milestones only.	Detailed schedules for all parts of assigned projects.
c. Financing each system (1) Budget formulation and justification.	Preparation of budget guidelines. Review and analysis of justifications from Centers. Justifies before approving authorizations.	Submission of estimates in accordance with HQ guidelines.	Same as present except for revised format and review processes.	Same as present except Centers assigned specific projects would submit complete estimates for their projects.	Same as present except with revised format and review processes.	Same as present except Centers would submit full estimates for assigned projects.
(2) Financial management and control.	Over-all financial operating plans prepared by HQ with periodic review of status.	Submission of recommended financial operating plan and periodic analyses and reports.	Same as present.	Same as present but by project.	Same as present.	Same as present but by project.
d. Progress evaluation.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.
e. Review and approval of changes in design or plans which significantly alter objective, schedule and/or cost.	By HQ.	For assigned subsystems and submission to HQ for approval.	By HQ.	By Project Center - prior to submission to HQ. Centers submit to Project Center.	By HQ.	By Center assigned a complete project prior to submission to HQ.

ANALYSIS OF THE DISTRIBUTION OF SPACE FLIGHT PROJECT RESPONSIBILITIES UNDER VARIOUS ALTERNATIVE PLANS

The Major Elements of NASA's Job	Assigning Over-all Integration Responsibility for All Projects to a Single Center		Creating a New Central Integrating Organization	
	Headquarters	Development Centers	Headquarters	Development Centers
1. Development of a long-range plan. a. Identify over-all programs. b. Identify program objectives. c. Identify gross schedules. d. Identify gross funding.	Same as present.	Same as present.	Central Engineering group providing material for programs scheduling and objectives.	Same as present.
2. Establish policies regarding intra-NASA and inter-agency liaison.	Same as present.	Same as present.	Same as present.	Same as present.
3. Establish broad agency-wide policies - e.g., reliability.	Same as present.	Same as present.	Central Engineering group material for policies - e.g., reliability.	Same as present.
4. Development of specific projects (Systems Engineering). a. Development of conceptual design.	Review integrated conceptual design as prepared.	Prepare for assigned subsystems and submit for integration by the single center assigned over-all integrating responsibility (the Directing Center).	Conceptual design by central group.	Submit suggestions as requested.
b. Development of preliminary design.		Develop as assigned by Directing Center together with contractors if and as assigned.	Central Engineering develop or assign to center or contractor and integrate total design.	Prepare for subsystems as assigned by central group.
c. Allocation of supporting research development and fabricating responsibilities - in-house and out-of-house.	General policy guideline on use of in-house and contractor capabilities to Center responsible for integration of all projects (Directing Center).	As allocated within itself and to other centers and contractors by the Directing Center.	Specific allocations to Centers and contractors within major policies on use of in-house versus out-of-house capabilities.	Subassignments within Centers and to contractors in accordance with HQ policies and allocations of responsibility.
d. Technical supervision of allocated responsibilities.		By the Directing Center.	In Central Engineering group.	For subassignments in-house and for supporting contractors.
e. Resolution of technical questions arising from interrelationship of work.	By HQ line organization on appeal from decisions of the Directing Center.	By the Directing Center.	By the Central Engineering group.	For subsystems within Center and those assigned contractors in accordance with decisions of Central Engineering group.
f. Testing and evaluation.	Review of test plans submitted by Directing Center.	Directing Center - prepare all test plans. Conduct or monitor tests performed by other centers or contractors.	Central Engineering group develop test plan and supervise tests performed by Centers and contractors.	Condust tests as directed by Central Engineering group.
g. Operating the system, including launching, data acquisition, data reduction, and data analysis.		By the Directing Center or one of the Supporting Centers as assigned by the Directing Center.	Under supervision of Central Engineering group.	Same general responsibilities as present but with additional technical supervision from Central Engineering group.
5. Managing specific projects (Sys. Mgmt.) a. Approval of conceptual design.	By HQ.	By Directing Center - prior to submission to HQ.	By HQ general management on basis of design submitted by Central Engineering group.	Only as asked for advice by Central Engineering group.
b. Scheduling each system.	Major milestones only.	Directing Center prepare and monitor all schedules.	HQ general management set major milestones; Central Engineering group draw up detailed schedules.	Preparing and monitoring schedules in detail for subsystems assigned by Central Engineering group.
c. Financing each system (1) Budget formulation and justification.	Same as present but with project estimates consolidated by single center.	Same as present for assigned subsystems except with submission to Directing Center for transmittal to HQ.	Same as present except with consolidation done by Central Engineering group.	Same as present except with submission to Central Engineering group.
(2) Financial management and control.	Same as present.	Same as present but through Directing Center.	Same as present with assist from Central Engineering group.	Same as present.
d. Progress evaluation.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.	Same as 5 b. above.
e. Review and approval of changes in design or plans which significantly alter objective, schedule and/or cost.	By HQ.	By Directing Center prior to submission to HQ.	By HQ with assist from Central Engineering group.	For assigned subsystem prior to submission to Central Engineering group.

EVALUATION OF ALTERNATIVE PLANS FOR ALLOCATION OF SPACE FLIGHT PROJECT RESPONSIBILITIES

Basic Criteria for Evaluating Alternatives	Alternative #1 Maintaining the Present Division of Effort	Alternative #2 Assigning Responsibility by Individual Project	Alternative #3 Providing Each Center Across-the-Board Capability	Alternative #4 Assigning Over-all Responsibility for All Projects to One Center	Alternative #5 Creating a New Central Project Organization
A. DOES THE PLAN PROVIDE EFFECTIVELY FOR THE MULTIPLE USE OF STANDARD LAUNCH VEHICLES?	Requires Headquarters technical competence and involvement to control modifications on "common use" launch vehicles.	Requires Headquarters Technical competence and involvement to control modifications on "common use" launch vehicles.	Requires Headquarters Technical competence and involvement to control modifications on "common use" launch vehicles and creates problems of dual relationships with vehicle contractors by dividing vehicle development responsibility.	Removes requirement for conflict settlement machinery in Headquarters by providing a central coordination point in the field, but assignment to Goddard or JPL could reduce objectivity by combining "common use" vehicle decisions with spacecraft and payload development.	Provides a central organization in Headquarters for coordinating the multiple use of all standard launch vehicles.
B. TO WHAT EXTENT DOES THE PLAN EFFECTIVELY FIX RESPONSIBILITY FOR SYSTEM INTEGRATION?	Doesn't provide any single focus with sufficient technical capability to resolve system integration problems quickly and effectively. Hence, system integration is given inadequate attention. Also, co-mingles "system engineering" and "system management" responsibilities in Headquarters to the detriment of both.	Clarifies responsibility for any given project by assigning subsystems integration responsibility for each project to a single center.	Markedly clarifies responsibility for any given project by assigning subsystems integration responsibility to a single center and providing the center with capabilities to handle all technical integration problems.	Provides a central point for the system integration job on all projects.	Provides a central point for the system integration job on all projects.
C. TO WHAT EXTENT DOES THE PLAN EFFECTIVELY FIX RESPONSIBILITY FOR SUCCESS OR FAILURE OF A GIVEN PROJECT?	Diffuses both system integration and subsystem development responsibilities among the centers, thus providing an open invitation for Headquarters staffs to become involved in details and a day-to-day "masterminding" of the technical work of the centers with a further diffusion of responsibility and accountability.	Fixes responsibility for any given project on a single center, but requires the center assigned responsibility for a project to rely on other centers for technical assistance.	Clearly fixes responsibility for success or failure of any given project since a single center would be responsible for and capable of handling all phases of a project once mission, experiment(s), funding, and over-all schedules were approved by Headquarters.	Fixes responsibility for system integration but requires the center assigned responsibility for a project to rely on other centers for technical assistance.	Fixes responsibility for system integration but requires allocation of subsystem development responsibilities among the centers.
D. DOES THE PLAN OPTIMIZE THE USE OF THE PRESENT CAPABILITIES AND INTERESTS OF THE CENTERS?	Makes maximum use of each center's primary capabilities and interests but denies the centers the psychological opportunities to be "end product oriented".	Takes advantage of the primary capabilities and interests of each center and the psychological advantages of being "end product oriented" which is more consistent with the centers' historical precedents.	Provides clear "end product identification" which would find wide acceptance in the centers, and, hence, would result in increased work satisfaction and productivity.	Makes maximum use of each center's subsystem development capabilities but creates a difficult acceptance problem for the two centers who would be denied "end product orientation".	Makes maximum use of each center's subsystem development capabilities and improves use of present capabilities by providing (1) more effective arrangements to define specific assignments at an early stage and (2) greater objectivity in resolving the in-house, out-of-house questions. However, it denies the centers "end product orientation" and places them in a "contractor role" with resulting relationship problems similar to those that have arisen between STL and Convair.
E. DOES THE PLAN MINIMIZE THE REQUIREMENTS FOR ADDITIONAL FACILITIES AND PERSONNEL?	Minimizes duplication of staff and facilities among the centers.	Does not create additional requirements for facilities and equipment.	Probably requires a considerable "leveling up" in terms of each of the three centers in both manpower resources (particularly important in scarce skill categories) and expensive facilities and equipment - e. g., launching facilities.	Probably requires some "leveling up" of the center assigned over-all integration responsibility both in manpower resources and equipment.	Creates a difficult staffing problem which might require an STL type of arrangement with all of its attendant "political overtones". Also requires complete facilities and equipment for the new central integrating organization.

EVALUATION OF ALTERNATIVE PLANS FOR ALLOCATION OF SPACE FLIGHT PROJECT RESPONSIBILITIES

(Continued)

Basic Criteria for Evaluating Alternatives	Alternative #1 Maintaining the Present Division of Effort	Alternative #2 Assigning Responsibility by Individual Project	Alternative #3 Providing Each Center Across-the-Board Capability	Alternative #4 Assigning Over-all Responsibility for All Projects to One Center	Alternative #5 Creating a New Central Project Organization
F. DOES THE PLAN MINIMIZE THE DISRUPTIVE EFFECTS OF CHANGE IN THE PRESENT ORGANIZATION?	Has the least disruptive effect on Headquarters-field and inter-center relationships and provides additional time to test out the present system and clearly identify the integration problems to be solved, before shifting to some other "untried" method.	Can be employed in conjunction with the present general distribution of responsibility with a minimum of disruption in organizational arrangements and is more readily acceptable to key staff than any of the remaining alternatives. However, it creates the problem of getting centers to work under the center assigned responsibility for a given project and presents difficulties in finding an acceptable and reasoned basis for project assignment.	Would have wide acceptance in the centers. However, it creates the image of "three little NASA's" which might be difficult to "sell" to the Bureau of the Budget and Congressional Appropriations Committees and probably requires a shift in Headquarters organization to reflect the across-the-board capabilities in the centers.	Requires additional shifting of work out-of-house from the center assigned over-all integration responsibility to provide necessary staff and facilities to handle the integration job effectively.	Requires the three space flight centers to shift to a "contractor role".
G. DOES THE PLAN PROVIDE FOR A REASONABLE WORKLOAD DISTRIBUTION (1) AMONG THE CENTERS AND (2) BETWEEN THE CENTERS AND HEADQUARTERS?	Leaves Headquarters staff insufficient time for planning, programming, and similar management functions by placing system integration responsibilities in Headquarters.	Removes the need for Headquarters involvement in the technical problem of matching subsystems.	Frees up Headquarters from involvement in day-to-day technical matters and therefore gives them more time for program planning and management, including the myriad of external relationships.	Removes the need for Headquarters involvement in the technical problems of matching subsystems but may place additional work on an already overburdened center.	Facilitates workload distribution among centers by making available more effective arrangements for defining specific center and industry assignments at an early stage. Also removes need for Headquarters involvement in the technical problem of matching subsystems and buttresses Headquarters staff groups for general program planning, supervision, and evaluation.
H. DOES THE PLAN PROVIDE FOR THE OPTIMUM ASSURANCE OF RELIABLE SYSTEMS?	Doesn't provide a single focus for system integration; therefore, system integration receives inadequate attention.	Fixes responsibility for any given project in a single center but does not provide corresponding capability.	Places responsibility and capability to develop and integrate complete systems in each center.	Provides for the rapid development of a superior system integration group by centralizing all project integration. However, it may dilute the effectiveness of the center's technical staff in its specifically assigned functional area - e.g., launch vehicles, spacecraft - and may not provide equal attention to all aspects of a system due to historical orientations and interests of the center.	Provides for the rapid development of a superior system integration group by centralizing all project integration. Also allows simultaneous defining of problems of major components and subsystem development, system integration, reliability, and scheduling, thus providing for preparation of initial over-all system engineering requirements, including sub-assignments for detailed definition and technical follow-through.
I. DOES THE PLAN PROVIDE FOR OPTIMUM FLEXIBILITY IN TERMS OF MEETING SHIFTS IN PROGRAM EMPHASIS?	Specifically assigned functional areas and lack of over-all project responsibility could make centers vulnerable to shifts in program emphasis.	Assigning project responsibility to each center and creating a pattern of responsive assistance among centers will provide more flexibility to meet program shifts.	Across-the-board capabilities in each center provide considerable flexibility in assigning projects and increasing or decreasing emphasis on a particular technical discipline.	Specifically assigned functional areas and lack of any system integration responsibility in two centers could make those centers vulnerable to shifts in program emphasis.	Specifically assigned functional areas and lack of any system integration responsibility in the centers could make all three centers vulnerable to shifts in program emphasis.

EXAMPLES OF INFORMATION TO BE INCLUDED IN STATEMENTS OF WORK

1. The purpose for which the service and/or research and development is required.

2. The objectives the government expects to realize by placing this particular requirement under contract.

3. A delineation of responsibilities of organizations within and without the government and their relationships to the contractor and to performance rendered under the contract.

4. The place or places where the work is to be accomplished.

5. The type of technical skills and/or disciplines which must be provided by the contractor.

6. A statement of required reports including the format for presentation.

7. A description of any supporting services, equipment, materials, or facilities to be provided by the government, and how they will be utilized.

8. Descriptions of work previously performed and the results.

9. Detailed statements of problems the contractor is expected to solve and a listing of areas in which solutions are mandatory if work is to be considered successfully accomplished.

10. Pertinent information on climate, working conditions, special equipment, transportation, and any hazards involved in accomplishing the work.

11. Test or quality control requirements.

12. Drawings or other documents having a direct bearing on work to be performed.

13. The government channels to be used by the contractor in obtaining information and guidance.

AN ANALYSIS OF NASA'S OPPORTUNITIES TO USE DOLLAR INCENTIVES IN PROCUREMENTS INVOLVING SIGNIFICANT ADVANCES IN THE STATE OF THE ART

Many of NASA's R&D procurements are characterized by:

1. An absence of significant production opportunities.
2. The absence of direct commercial applications except in a few fields - e.g., communications.
3. Complex technical unknowns.

Items 1 and 2 are significant because they make unacceptable to contractors the use of government-industry cost sharing techniques as incentives for cost reduction. The Atomic Energy Commission, for example, has used cost sharing on new reactor developments but based its applicability on a reasonable assurance of future commercial markets.

Item 3 raises the question as to NASA's possible use of dollar incentives, based on cost, time, or performance, as substitutes for CPFF contracts. We have concluded that technical unknowns involved in contracts requiring significant advances in the state of the art rule out such incentives as practical alternatives because:

1. Realistic targets cannot be set.
2. Peformance will be difficult to prove particularly in view of (a) the interdependence of components and subsystems and (b) contractor use of government-furnished equipment.
3. Extensive use of subcontractors make cost savings difficult to properly assign.
4. Contract changes may frequently alter the original cost base and require redetermination of incentive provisions.

These conclusions are also supported by the practices and experience of other agencies which can be highlighted as follows:

1. The Army has never been able to find any utilization of incentive contracts. *

2. The Air Force has prohibited the use of incentives on R&D procurements, thus confining their use to procurements moving into the production stage.

3. The Navy has considered and rejected the use of incentives on several of its weapon systems - e. g., Polaris and Eagle.

4. The Navy and Air Force, appearing before the Special Subcommittee on Procurement Practices in the Department of Defense, were able to cite only two contracts of 218 listed where targets had been exceeded and these involved total overruns of only $142,000. The Subcommittee reacted to this by saying: "The monotony of continuing profit, built-in and incentive profit, argues against Government negotiating competence and, for that matter, the reliability of savings figures."**

5. The Atomic Energy Commission has had disappointing results from its limited number of incentive contracts largely due to poor target setting - this in spite of prior cost experience - e. g., cost targets were badly missed in contracting for pressure gauges and transmitters although costs could be extrapolated to larger quantities.

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* - See testimony of the Honorable Courtney Johnson and General F. J. McMorrow, pages 249-250, Hearings of Special Subcommittee on Procurement Practices of the Department of Defense of the House Committee on Armed Services, April, May, and June 1960.

** - Report of the Special Subcommittee on Procurement Practices of the Department of Defense of the House Committee on Armed Services, June 23, 1960, page 31.

MAJOR SUBCONTRACTORS UNDER McDONNELL AIRCRAFT CORPORATION'S CONTRACT FOR THE MERCURY CAPSULE

Component or Subsystem	Contractor
1. Automatic stabilization and control system	Minneapolis-Honeywell Regulator Co.
2. Environmental control system	AiResearch Manufacturing Co.
3. Hydrogen peroxide control system	Bell Aircraft Corp.
4. Back-up hydrogen peroxide control jets	Food Machinery & Chemical Corp.
5. Batteries	Eagle Picher Co.
6. Communications system	Collins Radio Co.
7. Abalation heat shield	Cincinnati Testing & Research Lab.
8. Beryllium heat shield	Brush-Beryllium Co.
9. Parachute landing system	Radioplane Division of Northrop Aircraft Corp.
10. Escape rockets	Grand Central Rocket Co., Inc.
11. Retrograde and posigrade rockets	Thiokol Chemical Corp.
12. Navigation periscope	Perkin Elmer Corp.
13. Horizon scanners	Barnes Engineering Co.